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VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

1st QUESTION.

CONSTRUCTION
OF SHIP CANALS AFFORDING OPERATION AT HIGH SPEED.

REPORT

BY

Herr GRÖHE,
Wasser-Bauinspector, Münster, Westphalia.

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INTRODUCTION.

The question we undertake to examine has in some of its aspects been the object of discussion in previous Congresses.

The last Congress at Paris considered the first question, viz. the „Consolidation of the banks and talus of canals; the means in use for the consolidation of the banks and talus with respect to navigation at *high speed;* the results; the expense of establishment; and the influence of the *width of the channel.*

In the sixth question „Traction of boats on canals" was considered, so that several essential parts of the programme have been discussed.

The first question of the Sixth Congress comprises the examination of all the relations existing between a boat travelling at high speed, the wet section of the canal and the consolidation of the banks. These relations must be made clear by experiments and the results submitted to a critical examination.

It would be difficult to treat all the points of this large programme in a strictly limited report, even if the necessary experiments had been made in sufficient number. As regards Germany, this has not been the case and the observations given in this report respecting the different points of the first question, observations which refer only to *inland navigation canals* must be considered merely as an attempt to comply in some measure with the demands of the programme.

I. INFLUENCE OF THE DIMENSIONS AND THE FORM OF THE SECTION OF THE CANAL ON THE SPEED AND THE NECESSARY TRACTION POWER.

For reasons which we shall explain later on, it has been generally more easy to determine the force of resistance for boats and trains of boats in *free rivers* of a sufficient width and depth, than it has been to estimate the traction power in *canals of narrow section.* In any case, in spite of the numerous experiments which have been made up to the present (1), it has not been possible to establish rules which could be safely applied to the various proportions between the submerged section of the boat and the different speeds of working.

Nor do the experiments of Herr MOHR on the canal from the Oder to the Spree (2) appear to have furnished sufficient basis on which to found a general formula respecting resistance.

Perhaps the most important experiments are those which have been lately made in Holland according to which a perfectly realisable speed is found to correspond to a determined proportion between the wet section of the canal and the immersed section of the boat and cannot be augmented by an increase of engine-power (for screw-boats).

Nevertheless, the observations which have been made up to the present are scarcely yet sufficient to be utilised for determining a section of canal which would be in all respects most favourable. A more scientific foundation for the rules laid down at the Vienna Congress is therefore still wanting.

Importance of traffic, manner of working, the tonnage and the speed of the boats and the wet section of the canal are all mutually correlative. All the experiments proposed by the programme have therefore as object the solution of the following problem:

Given a determined movement of traffic, how is to be arranged the section of the canal, the shape and speed of the boat in such a way that the expense of construction and maintenance of the canal and the working of the boats would reach their minimum? The speed of the boat has a most decided influence in deciding the section of the canal, and it should be observed that a *more rapid* and *more regular* working can be regarded with preference only for the canals on which *a larger traffic* either already exists or is expected.

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(1) Compare the experiments of Herr SCHNELL with trains of boats on the Rhine (Zeitschrift für Bauwesen 1889), as well as the valuable experiments communicated to the Paris Congress by MM. DE MAS and CAMERÉ.

(2) Compare Zeitschrift für Bauwesen 1891.

The increase of the working speed is limited:

1st by the nature of the consolidation of the talus.

2nd by the size itself of the section of the canal.

When the navigation is effected by screw-boats, even when the banks are sufficiently consolidated, the increase of the motive power beyond a certain degree will have no other result than to increase the number of revolutions of the screw and to augment the working of the wash upon the banks. It is, nevertheless, true that the utility of the canal depends on the increase of speed so long as the size of boat remains the same. The profit or utility of a canal is frequently misunderstood, probably because the signification implied does not correspond exactly to the real meaning of the word. Generally the utility of a canal is understood to mean the maximum number of kilometric tons, which can be transported on the canal in one year. It is, however, clear that this number of tons only depends on the capability of the locks to admit a given number of vessels at a time.

By increasing the number of locks at the extremity of each reach, or by reducing the time required for double lockage, or even by increasing the time of working, the utility in this sense of even a small canal could be increased to any desired extent. In fixing the signification in this sense no regard is paid to the average time required by each boat for the journey, which on the other hand determines the number of boats required for working all the traffic.

Theoretically, therefore, by *the greatest utility of a canal* should be more correctly understood, the manner of working and the size of the boats being given, *the number of kilometric tons* which can be furnished by *boats fully laden* working regularly in a unit of time *with a minimum of duration of voyage for each boat.*

Taking several canals of equal traffic and equal means of transport, the one which averages the greatest kilometric traffic with the smallest number of boats will furnish the greatest degree of utility.

The real annual utility of a canal will of course be always much below *the greatest utility theoretically possible.* Still endeavours should be always made by the removal of hindrances to navigation, by the establishment of regular working and by the improvement of plant to approach as nearly as possible to the point of theoretical utility.

In determining the sections of canals it is a most general necessity to reduce to a minimum the expense of transport. The difficulties in the way of determining them are enormous, because, given the amount of the traffic as well as the manner of working and the tonnage of the vessels, the speed of the latter would still depend on the section of the canal and the consolidation of the banks.

The examination becomes still more difficult when it is desirable to take a decision with regard to the tonnage of boats when new canals are to be constructed, because the section of the canal depends in the first place on the size and form of the boats.

It is evident that if the boats are small the section of the canal may be less, or that the working speed may be greater. Besides, the capacity of the transport of boats is limited by the utility of the places for loading and unloading, that is the opportunity for transhipment. On the other hand the expenses of transport per ton for small boats increase very rapidly.

It will therefore scarcely be possible to come to a general decision; it will be necessary to consider each case in particular, taking into account the economical interests, the position of adjoining waterways and the size of their section.

In any case it is certain that the tendency to augment the tonnage of boats is so pressingly evident, that a few considerations of an economical nature cannot weigh against it. Proof of this fact has been furnished by all large waterways with large traffic.

In the figure on plate IV for example a table will be seen which is taken from the navigation registers of the development of the structure of boats belonging to the fleet of the Rhine from 1848 to 1891; these boats are of more than 500 tons.

The increase of the tonnage of the entire fleet of the Rhine is to be seen on plate V.

According to these statistics the tonnage of the 950 ships of more than 800 tons each in March 1892 was equal to the total tonnage of the remaining 5178 boats of the fleet.

Lately the same tendency to an increase of tonnage of boats has been noticeable on canals, especially in cases where the canals adjoin a river with sufficient depth of water.

However, on canals of generally narrow section, this tendency to enlarge the tonnage and the speed of boats encounters a great difficulty, to which hitherto too little attention has been paid, viz. the loss of speed occasioned by the crossing of boats.

In the first place it is evident that when with a heavy traffic the canal can only be traversed very slowly the number of crossings will increase enormously; and this will occur in a greater degree as the tonnage of boats is less, because then the number of boats necessary must be larger.

Although at the Vienna Congress no objection was made to the theory that the crossing of boats has but a slight influence on the determination of canal sections, as long as the total space between the boats and the banks at the level of the line of deepest immersion is 3 m., it must be admitted, after what has been said above, that the influence of these crossings in such narrow waterways must really be taken into consideration. Therefore it is necessary to examine the principal points connected with these questions.

I wish expressly to point out that it is here merely a question of a superficial calculation; but these calculations already lead us to acknowledge the importance of the subject, especially with reference to the maintenance of a regular working at high speed.

The influence of hindrances to navigation, particularly the crossing of boats, on the determination of the section of canals of extensive traffic and rapid working.

As far as I am aware, the influence of hindrances to navigation on the average speed to be obtained on canals of small section has hitherto only been discussed in a most general way, as the necessary scientific data for an exact solution of such problems are wanting, and practical experiments on canals with an active traffic by means of boats of large dimensions or large tonnage have not yet been made in sufficient numbers.

The delays and stoppages occurring on almost all canals where the traffic is increasing were generally considered as inevitable and inherent to the nature of the canal, the interruption by locks necessarily putting great difficulties in the way of a regular working. It was believed that no remedy could be found for this loss of time except by *increasing the capacity of the locks.*

This measure is suitable for canals with long reaches, where the boats meet with few hindrances and can make full use of their speed between two locks; but it is insufficient when boats which have to travel as quickly as possible, in order to lessen the duration of the journey, are obliged to navigate in a narrow canal which is full of hindrances.

In the following examination it will be shown that the favourable influence which the widening of narrow canals exercises on navigation may be calculated within certain limits; and that this influence, even under the most favourable conditions of working, acquires exceptional importance where the traffic is pretty considerable.

The real principles for such a calculation of the loss suffered in crossing and its influence in determining the section of canals of large traffic and rapid navigation have already been given by the author of this report in his report of July 1891 on the advantages of widening and deepening the canal from Dortmund to Ems.

A. *Influence of hindrances to navigation on the movement of the boat in a canal without locks.*

1. *Distance travelled in the time* **t**, *taking into account the delay caused by hindrances.*

The admissible working speed v depends on the available motive power, the nature of the consolidation of the banks and the wet section of the canal. This speed is lessened:

1st *by hindrances to navigation*, such as, bridges, safety gates, the resistances of curves, crossing with other boats and by the influence of wind and waves;

2nd *by certain obligatory stoppages* caused by the rules of working, or in consequence of circumstances brought about by the nature of the working.

If, according to Plate I, fig. 1, we designate by $X = x_1 + x_2 + x_3 \ldots$ the sum of those parts of the canal in which the boat can travel at full speed v; by $A = a_1 + a_2 + a_3 \ldots$ those parts of the way on which variations of speed have to be made on account of hindrances; by v_m the average speed throughout the distance A; and finally by $B = b_1 + b_2 + b_3 \ldots$ the distance the boat could have traversed at the admissible speed during the time it was stopping, the time t necessary for covering all the distance is expressed by the following equation:

1)
$$t = \frac{X}{v} + \frac{A}{v_m} + \frac{B}{v}$$

From this expression with the known values $a_1 \ldots b_1 \ldots x_1 \ldots$ the distance X may be found on which full speed prevails for a determined time of navigation, namely:

2)
$$X = tv - \frac{Av}{v_m} - B.$$

The distance travelled L traversed by the boat in the time t is given by the equation

$$L = X + A.$$

By replacing X by its value as in 2) we have

3)
$$L = tv + A - \frac{Av}{v_m} - B$$

and thence the general equation for the working

4)
$$L = \underset{S}{tv} - \underset{s}{\underline{A\left(\frac{v - v_m}{v_m}\right) + B}}$$

5)
$$L = S - s.$$

2. *Conclusions arrived at from the equation.*

In the equation the first member tv signifies the distance S which the boat would traverse without hindrances; the second member s *the distance lost by hindrances.*

The equation holds good only so long as $X = or > o$ thus, according to equation 2)

$$6) \qquad tr = or > \frac{Av}{v_m} + B.$$

If $X < o$ the full speed cannot be attained at any point of the distance travelled, and the average speed influenced by B becomes less than v_m. It is however evident that in the general equation for the working *the case of lockage must also be included* as soon as by a is understood *that* part of the distance which the boat has to traverse from the point before the lock, at which the speed has to be lowered, up to the point behind the lock, at which the speed v is again taken up.

B. *Influence of hindrances to traffic on the navigation in a reach of a canal.*

1. *Division of the reach into known sections. Fixing of principles.*

If it be wished to attain in the reach of a canal with a given maximum speed v the maximum of traffic together with the *shortest* duration of the journey and the *least* use of water in the locks, it is necessary that after each locking the boat entering be immediately replaced by one leaving.

This necessitates a *regular working*; thus a division of the reach into working parts, which are traversed by the boat in the same time t as it takes it to traverse the distance l_0 at the place where the lock is. (Compare fig. 2 Plate I).

The length of the parts l_1 l_2 l_3, the amount of the hindrances being known, could be determined according to the general equation 4).

With a regular working there will be two crossings in each part of the reach, one always at the end and the other at a place on its course to be fixed with regard to the hindrances to navigation. It follows immediately that *the greater the hindrances to navigation in the divisions, the smaller will be the length* l *of these divisions, and consequently the more numerous the crossings in the entire reach.*

As the hindrances are greater or more numerous, the number of crossings necessary for the maximum traffic increases and, with the inevitable loss of speed at each crossing, which again influences the length l of the divisions, must exercise an extensive influence on the average speed of working on canals with large traffic.

If stoppages occur in the traffic, and they are only caused by irregular working of navigation on a free way, in spite of the locks being sufficient for the greatest average daily traffic, the number of crossings must increase or the average speed of the boats must suffer a diminution still more considerable. The same occurs when at certain times the traffic is larger in one direction than in the other. The disadvantage caused by the crossings will then be strongly felt, for it will be difficult to procure quickly enough the boats necessary to compensate for the delays.

If during a certain time boats are locked from one direction only, they will, on account of the shorter time required, follow each other at shorter intervals and considerably delay those coming from the opposite direction; consequently with a working of this kind a larger number of boats will be required in order to balance the delay caused in the transport of goods. This is of the greatest importance to transport companies whose interest it is to use the least possible number of boats in order to lessen their working expenses. With a sudden increase of traffic, for example, immediately before or after the closing of navigation, before or after the locking of the canal, also at times when transport by water is augmented on account of an interruption of railway traffic, the necessity of shortening the duration of the journey and a more rapid succession of boats is most imperatively felt.

All these considerations show, even without the aid of figures, that on large canals with an active traffic hindrances to traffic should be diminished as much as possible.

2. *The meaning of unit of reach.*

If in a regular working of locks we regard as hindrances to navigation *only the crossings*, the divisions l of the reach, which correspond to the distance the boats navigate in one direction, become *equal to one another*. The length of such a division for a given working speed may then be taken as a unit for fixing the loss by crossings or the difficulties of working; and this length we shall in future designate for determing by the expression *unit of reach.*

The unit of reach, including the delay caused by double crossing, can thus be traversed by boat in the same time in which a double locking can be effected; this time t must be determined on the hypothesis that a boat effects its first crossing with the boat which is about to take its place in the lock immediately after leaving the lock and with the *smallest loss of time possible.*

With regard to the above conclusions, every hindrance to navigation by reducing the average speed of the boat shortens the length of the divisions of the reach and thereby increases the number of crossings; these difficulties increase with every irregularity in the working and with variations in the amount of the traffic; under these conditions a calculation of the losses of speed, with exclusion of all hindrances except crossings, will give in round numbers the loss as *much less considerable* than if account were taken of other hindrances which might exist.

Therefore the total removal of hindrances by a widening of the section of the canal must be of greater importance than calculation would give us.

C. *Examination of losses of speed caused in a reach solely by crossings.*

The different kinds of working may be divided into two groups namely *constant* and *variable* forces.

1. *Constant working.*

The working of constant forces comprises those sorts of movements in which the motive power is in such connection with the boat that it cannot be controlled by a brake, but must be completely interrupted when it is necessary to moderate the speed. To this kind belongs towage (worked from the bank). When the section is so narrow that the working speed must be moderated for crossing, the loss of time caused by the interruption and re-establishment of the connection with the motive power, during which the boat lies still or has no regular movement, must according to the equation 4), be represented by a quantity b (compare sub-division E). As in the unit there are two crossings the length of the unit should be expressed by

$$7)\qquad l_c = t\,v - 2\left[a\left(\frac{v - v_m}{v_m}\right) + b\right]$$

As soon as in the constant working any mechanism is introduced, which allows of the moderation of the speed by the aid of a brake, the working of the power may, as regards the boat, be considered here also as variable.

2. *Variable working.*

Under this head are comprised other kinds of working, as, manual labour, towage by horses, by locomotives, tug-boats, electric power, etc.

From fig. 3 Plate 1, where the movement of two crossing boats is shown by indicating their speed at each side of the water-lines and by representing some of the positions of the boats, it is evident that the speed for each boat becomes the same. The length of the crossing a_0 must for safety be taken longer than *one* boat's length, in order that the boats at the most critical moment, just before the commencement of the crossing, will undoubtedly have attained their minimum of speed. From equation 4) it follows for this special case, since $b = o$:

$$8.\qquad l_v = t\,v - 2\,a\left(\frac{v - v_m}{v}\right)$$

The loss of speed for a train of boats drawn by a tug must be calculated in the same way.

D. *Determination of loss of speed in crossings in a canal of narrow section compared with a wide section.*

For the following discussion we take as a basis the wet section of the canal shown in fig. 1 Plate I which has a bottom width of 14.0 m. and a depth of 2.0 m., and a section of a boat of 6.5 m. width and a draught of 1.70 m.

The section of the boat is the largest chosen in proportion to the width of the locks, which is 7.0 m.

There are canals of a similar section in the working of which the locks allow a passage to still larger vessels.

The proportion between the wet section of the boat and the wet section of the canal, 1 : n, and the forces of traction do not suffer such considerable change by a moderate widening that on this account alone a widening can be regarded as necessary.

Thus, for the section we have taken 1 : *n* increases by a widening of 2.0 m. from 1 : 3.6 up to 1 : 4.0 while the power of traction decreases from 535 kg. to 503 kg. (1). On the other hand great importance must be attached to the *spaces between the boats and the banks* at times of crossing as these exercise the greatest influence on the crossing of long and heavy boats. Although the experiments made up to the present do not allow of the most appropriate measure for these spaces being determined, it must be acknowledged that a widening, however small it may be, of the section of a narrow canal will afford great advantage in crossings. In keeping the same space of about 1 m. between the two boats, the widening of the canal will increase the spaces between the boats and the banks, which is of the greatest importance to the steering power of the boat.

It is beyond all doubt that the steering power of the boat at times of crossing cannot be maintained when the spaces between the boats and the banks are too narrow, and that collisions and serious damage cannot be avoided, unless the speed of the boats be *considerably* moderated. Formerly no thorough examination of the question of loss of speed at times of crossing was made, probably because the traffic at the time of the commencement of the working being generally estimated of rather small extent it was believed that these losses of speed would not have much influence on the regularity of the working or on the increase of the working expenses.

For determining the loss of speed to be expected there are certain data which should not be neglected; which although they cannot be proved by figures can be well justified by the nature of the working. Changes in the crossing space, if not too great in proportion to the extent of a traffic, have no real influence on the result, as is shown by calculation and will be proved later on.

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(1) According to the formula of MOHR $P = 140 \left(\frac{A^2 \, v^2}{2 \, A + C}\right)$ for $v = 1,4$ m.

In working with *constant* power, at a speed of 0.8 m. or 1.0 m., it is dangerous in the narrow section of the canal to give to two boats at the same time the full working speed at the place of crossing. Either one of the boats must remain motionless against the bank and wait until the other has passed, when it must be pushed oft and again attached to the rope, or both boats leave the rope and pass each other, in which case propulsion by hand could give a speed of about 0.30 m. and then be reconnected with the rope. In both these cases the loss of speed would be the same for one boat as for the other.

By reducing b to a narrow section v_m approaches more to the value of variable working power; and the same applies to funiculair traction with a brake.

When the working is effected with variable power it must be admitted that in a narrow section, when boats cross, the speed is diminished to 0.3 m., and in order to avoid collisions the brake should be in action at more than one boat's length before the crossing takes place. On the contrary in a wide section the speed need only be reduced to 0.8 m. and the brake need not work so soon, because the diminution of speed is less considerable and the steering power is greater.

This maximum speed of 0.8 m. at the place of crossing is maintained in widened sections for speeds of 1.0 m. up to 1.4 m., although it appears that a speed of 1.0 m. can be attained. In any case, in order to avoid collisions, the boat should moderate its speed in good time by using the brake, and the distance at which it should commence to use it should really not be less. (Compare fig. 5, Plate I). On the other hand it appears allowable to somewhat shorten the distance within which the boats may again use full speed after the crossing.

The same manner must be followed in determining v_m for the formation of a train of two or more boats. As the danger in the crossing of two trains is greater than in the crossing of two single boats a relatively greater distance and a minimum speed must be allowed; and for the narrow section account should be taken of the greater distance at which the change of speed should be effected. For the present we will discuss only the loss of speed in the crossing of *two single boats fully loaded.*

No great exactitude is in any way claimed for the values of v_m for different working speeds v, formed according to fig. 5, Plate I; but we may grant with sufficient safety that for a purely superficial examination the divergencies are within allowable limits.

According to this, to prove the favourable influence of a widening of the section, these average values v_m may be employed without thinking further of the calculation.

E. *Comparison of the loss of speed in a narrow section and a widened section and a graphic representation of the results.*

1. *Relation between the amount of traffic, duration of time of locking and the unit of reach.*

From equation 8)

$$l = t v - 2 a \left(\frac{v - v_m}{v_m}\right)$$

it appears that the increase of the unit of reach within the limits of equation 6) agrees precisely with the time t, as the second member, namely the way lost remains constant.

The duration of a double locking, including the time for the distance which the boat must traverse before and behind the lock until the first crossing is reached, determines, as has been said above, the unit of reach, that is: *the distance between boats or trains navigating in the same direction.*

The distance l_0 from the first crossing *before* up to the first crossing behind the lock was therefore a known quantity.

In the calculation of the value of l_0, or of the unit of reach, it must be supposed that the traffic existing on the canal is sufficient to keep the locks continually at work; for it is only with a regular working without stoppage that the boat leaving the lock can be replaced by another entering with the least possible loss of time.

If the traffic does not reach this extent, it is clear that the boats after each double locking will not effect the first crossing immediately before or after the lock, but that a greater distance will be traversed from the lock to the first crossing. In this case l_0 represents a variable quantity, which becomes greater as the daily average traffic is less. The fault thus committed for the determination of the unit of reach would not be of much importance except for very short reaches, for which on other grounds this entire study has no practical signification. The same view applies to a case of growing traffic.

For the maintenance of a growing traffic the necessary number of locks should be constructed side by side and the distance between the navigating boats will become less. The equation for the distance of isolated boats

$$l = t v - 2 a \left(\frac{v - v_m}{v_m}\right)$$

suffices therefore with *sufficient general exactitude for any amount of traffic* as soon as the time t, which corresponds to the amount of traffic, is determined. If, for example, the yearly traffic is A tons, supposing an annual lock-time of 270 days of 10 hours and a cargo of 400 $(1 + {}^1/_5) = 480$ t the double locking will be found to be:

9) $$\frac{A}{270 \times 10 \times 60 \times 480} = t',$$

in which t' signifies the number of minutes occupied in double locking with the distance l variable according to the amount of traffic A.

In fig. 1 Plate II the values for the distances of boats with increasing duration of locking are given for the speeds $v = 1.0$ and 1.4 m.; and the annual amount of traffic given is calculated according to the equation 9). From this figure it appears that, with a lesser working speed, the distances of the boats decrease whilst the loss by crossings increases.

2. *Determination of the distance in the unit of time.*

The distance in the unit of time can be immediately found from equation 8) by dividing by t'

10) $$S = \frac{l}{t'}$$

The results of this calculation are shown in fig. 2 Plate II above the axis. Strictly speaking the exact value of S for the calculation of the time of working on the whole length of the canal can only be applied when different reaches L between the places of locking, divided by the measure of the unit of reach, give an integral number, as was shown in B.

It is, however, at once evident that if this be not the case the average, working speed of the canal becomes so much less, the length of the unit of reach is reduced and the number of crossings in a regular working is increased; so that by the introduction of the above unit of distance S the value of the loss by crossing will be less and the advantages of the widening will be greater than was calculated.

3. *Representation of the increase of distance per second by means of widening of the section.*

The results of calculations appear most clear when the increase of speed based on the unit of distance is shown. Let us represent the distance per second in a narrow section by e, the distance per second in a widened section by w and the gain on the enlargement will be

11) $$Z = \left(\frac{w}{e} - 1\right)$$

The values $\left(\frac{w}{e} - 1\right)$, which are calculated for the two speeds 1.0 and 1.4 metres and are shown beneath the axis of fig. 2 Plate II, represent therefore the saving in distance which may be attained by widening of section.

From fig. 2 it follows that the loss by crossings has less influence on the economy of time in navigation when the working speed increases, for the units of reach corresponding to the greater speed become longer. Nevertheless the economy, at a speed of 1.4 m. with an increased traffic, is very considerable; this speed however, for practical reasons, cannot be much exceeded, or the movement of the water would wash away the bottom and the banks of the canal.

F. *Demonstration of the return for different amounts of traffic in consequence of the increase of section.*

1) *Reason for laying out capital in widening.*

In order to judge of the return, it seems necessary to calculate not only the interest on the capital employed but likewise amortisation. It will be sufficient to require about 3 % interest and 1 % amortisation on the cost of construction. Besides this it is absolutely indispensable to establish *supposed economies for different degrees of traffic*, and to establish that even for a traffic, not above the lowest which can be expected, the application of the rules remains economically justified.

In widening, when the annual traffic remains the same, the economy is effected on the working expenses of the canal in proportion to the greatest average speed and in relation to the interest on the capital engaged in the working, *only when* all other real advantages, which are too numerous to specify, are provisionally left on one side, especially the great importance of increased security in the working of the traffic.

2) *Determination of the expenses of working.*

As a basis for the expenses of working the report of SYMPHER „Expenses of transport on railways and canals" pages 20 and 21 may be taken. Among them are counted:

a.) the working expenses of navigation on the journey of 247 km. on the canal from Dortmund to Ems, taking as basis an annual traffic of 1.3 millions of tons, going and returning (the journey as far as Emden full freight, returning 1/5 freight) for the net kilometric ton at an average of *0.391 pfennigs* for going and returning, under the supposition of a regular working without interruption existing up to the present at the locks. (Compare page 14 of the report.)

b.) The interest of the working capital at 0.077 pfennings, therefore a total of 0.469 pfennigs. For this a total of 0.4 pfennigs only will be taken. SYMPHER has already discussed the return of this sum, which represents also about a sufficient and just average value for the expenses.

If the expenses are found to be really less, the superiority of transport by canal over transport by railway with regard to cheapness is proved and a widening of the canal for the facilitation of navigation is justified. If the working expenses are greater than here given, the economy actually realised is larger in proportion. In the working expenses it must be taken into consideration that the outlay for working power in a widened section (for example for steam power) is certainly higher, for in order to traverse a longer distance in the same time, other conditions being the same, a greater power is employed.

But we may consider that an important part of this surplus power used is compensated for by the greater regularity of the working and the lessening of the traction power necessary on all the course of the enlarged section, as also by the employment of greater power for the attainment of the full speed in a narrow section after crossing.

According to the data of SYMPHER the cost of the working power alone per net kilometric ton amounts to 0.04 pfennig, and the annual traffic is accounted to be equally divided, so that the crossings are reduced to a minimum. This last circumstance influences the result very considerably as will be shown later on. The amount of the traffic A being known and the figure of 0.004 mk. being given for the net kilometric ton, the economy in working expenses for the kilometre in length of canal may be determined by multiplying Z (equation 11) in a widened section; thus

$$E = A \times 0.004 \times Z. \tag{12}$$

The quantity Z must be taken in proportion to the amount of the traffic from fig. 2 Plate II.

For example if $A = 1.3$ millions of tons (in proportion as $t^1 = 60$ minutes) the part $Z = 0.11$ and thus:

$$E = 1300000 \times 0.004 \times 0.11 = 572 \text{ Marks.}$$

On Plate III the values E, d, h, that is to say the economy per kilometre of length of canal are given. They serve for different degrees of traffic by reason of a sufficient widening of the section of the canal with the supposition of working speeds $v = 1.10$ m. and $v = 1.4$ m.

It will be seen that with a great increase of traffic *very much greater economy is obtained.* Thus for a traffic of 1.3 millions of tons the saving amounts to 572 marks; for 5.18 millions of tons 13880 marks, or more than 24 times as much. Consequently, on canals of large traffic, even when the losses of speed are less than shown in fig. 5 of Plate I, the saving effected by the choice of a sufficiently wide section amonts to a very considerable sum.

3. *The limits within which the widening may be effected.*

In a narrow canal, which leaves little free space between the boats and the banks, a perceptible increase of speed may be rendered possible by widening somewhat this free space at the places of crossing and advantage may be taken of it by developing full speed as soon as this space has attained a certain limit so that a more ample widening would be of no use. But on account of the expense such wide sections should only be built when an unusually large extension of traffic and favourable conditions of bottom can be counted upon. In general a lesser widening will suffice to obviate the principal difficulties. It is unfortunately not yet possible to determine with sufficient exactitude the degree of widening which would lower to the desired extent the loss by crossing. In the section taken as example 14 m. wide at bottom, a comparatively small widening of 2 m. will considerably diminish the difficulties in crossing, as by keeping an average free space of one metre between the boats, the free spaces between the boats and the banks are doubled.

In order to determine the return resulting from a widening of 2 m. we must suppose, taking as basis the approximate calculations for canals of similar dimensions, that the cost of construction amounts to 300000 marks and that the cost of each supplementary metre of width *within the limits which we are now considering* may be estimated at about 2 °/₀ of the cost of construction.

Therefore, in view of the interest and amortisation of 4 °/₀ upon this supplementary construction capital, the saving realised by a widening of 2 m. must amount to

$$2 \times 300000 \times \frac{2}{100} \times \frac{4}{100} = 480 \text{ marks.}$$

According to fig. 1 Plate III this is the result for a speed of 1.0 m. with a traffic of 1.0 millions of tons, and for 1.4 m. speed with a traffic of 1.1 millions of tons.

Any objection to this manner of calculation as being too favourable disappears, if we consider that the annual traffic is never equally divided, but, on the contrary, increases very much at certain times, while at other times it sinks below the daily average.

4) *More exact calculation of the saving for a given traffic.*

In concluding these observations we may point out as a given example how the fluctuations of traffic, even with a regular working, influence the average saving in working expenses, and how they decidedly show the benefit of widening narrow sections of canals.

Let us take for an annual traffic of 1.3 millions of tons the approximative division of traffic, as it is given in fig. 6 of Plate I.

According to the equation 12, admitting for Z the values of fig. 2 of Plate II the economy is 858 marks per kilometer [for a speed of 1.4 m.; and 1012 marks for a speed of 1.0 m. The saving on the 20 days of greatest traffic alone amounts for $v = 1.0$ m. to

$$\frac{20}{270} \times 3900000 \times \frac{4}{1000} \times \frac{40}{100} = 462 \text{ marks,}$$

thus, nearly covering the expense of a widening of 2 m. No mention is made here of the saving resulting from the diminution of traction power in an enlarged section, nor of the *unusually important advantages resulting from greater facility in working.*

In this regard it should not be forgotten that crossings in a narrow section always present a dangerous difficulty to navigation, which becomes greater as the section is narrower, so that the increase in the number of these difficulties with a large traffic may render the establishment of a sure, regular and rapid working impossible on narrow canals.

G. *Consequences for canals with a large traffic.*

1.) In narrow sections with a very low speed of about 0.3 to 0.4 m. per second the number of crossings is very large, and on the contrary the loss of speed by crossings nearly nul. With a speed of 1.0 m. the number of crossings diminishes but the loss of speed at the crossings increases very rapidly.

When the speed, which for other reasons should not exceed certain limits, is increased the general loss of speed becomes slowly less. By widening sections of narrow proportions important advantages, such as economy in working expenses may certainly be obtained, even under unfavourable conditions, and even when the traffic extends to about 1000000 tons; this applies to all modes of working, and in general for all rapid working speeds which come under our consideration.

2.) The advantage of widening is above all apparent when the traffic increases, and when it is subject to inevitable fluctuations, from which arise difficulties in the maintenance of a regular working.

In a narrow section, even when the traffic does not much increase, the possibility of a regular working is rendered so difficult, that there is quickly a gathering of boats at some locks, while others are not fully utilised; so, that in order to avoid long delays, which cause a considerable loss of time to navigation, recourse must be had to the building of second locks, or to the establishment of a night service much sooner than on an enlarged section, which guarantees a regular traffic to the boats. The widening also admits the possibility of boats in local service and the principal through traffic on the canal to travel undisturbed side by side. The construction of numerous small harbours, and also of private harbours would evidently result in an animated local traffic, which in a narrow section would place serious difficulties in the way of the regular working of the principal through traffic.

3) Certainly in the first period of working in most cases crossings will

only occur between loaded boats and empty boats or boats partly loaded, and consequently, even in a narrow section the free spaces between the boat and the banks will be a little more than given above if the necessary order of navigation be observed.

It would, however, be an error to base the widening on this fact, for, in time and very quickly the cargo of the boats will increase with the increase of freight on the canal and then the free space will no longer be sufficient. But, even supposing that a crossing of two fully laden boats would be comparatively rare, with an increase of this kind crossings cannot be *quickly and safely* effected without widening the canal. It will, mostly, be easy to arrange that the boats in crossing are at some little distance from each other. On the other hand, it is much more difficult to steer the boats in such a way that the respective distances of the boats from the banks remain nearly equal. It will easily happen that the boats have to remove from the position required for crossing with regard to the axis of the canal; with a very small turn one or the other of the boats will unavoidably touch the banks, the more so as the banks cannot be constructed and preserved at all points equal and exactly in conformity with the projected section; on the contrary there are numerous small irregularities, which increase the danger of collision. Besides, even with a moderate wind steering will be effected with considerably greater difficulty by empty boats and boats with small cargo. With the unequal division of traffic, which increases considerably for a few days during the period of navigation, the advantages of widening augment so rapidly when there is an increase of traffic that a return even under unfavourable suppositious circumstances can, as a rule be relied upon.

4) Even with a traffic of a million of tons, it is not in any case prudent to construct a narrow section for the sake of economy and to postpone the widening until later. As soon as the traffic increases the narrow section will be seen to be insufficient and a complementary widening will be necessary, which can then only be made at great expense and derangement to the service and by completely removing *at least one* bank of the canal. Besides this, the width of the towing paths will be unequal unless the necessity of the later widening had been taken into account at the time of construction.

It appears reasonable to allow from the beginning a sufficient measure to the expenses to cover the cost of widening and not to wait until the incaease of traffic *necessitates* this widening. In fact the cost of the extra width at the time of construction is comparatively small in the total amount of the cost of construction, whereas, for the reasons above given the widening after the canal bas been put in working generally meets with immense difficulties and demands large pecuniary sacrifices.

It is also a question if the postponement of the widening until the time when the traffic increases, does not in itself delay or hinder the increase. This is most probable where the prices of transport by water differ but little from the prices of competing railway lines. In this case it will scarcely be possible to obtain, as was projected at the time of construction of the canal, the impulsion to the extension of the traffic, that is to say, an absolute increase of traffic without prejudice to the railway traffic.

5) After the widening the working of the wash on the banks, principally in the crossings, will be considerably lessened; from which will result a saving in the expense of erection and maintenance of the consolidation of the banks, or the possibility of proportionately increasing the working speed.

6) Finally, let us briefly consider an exceptional case. If, in advance, a traffic may be expected of such importance that the distance between the boats going in the same direction approaches perceptibly to the sum of the two lengths of crossing, the possibility of the maintenance of a regular working is very doubtful. This may be remedied by making the canal sufficiently large to allow of three boats navigating conveniently side by side, or by forming the canal for two boats in such a way that the distance between the boats be reduced in a suitable manner by increasing the size of the vessels of transport.

But, as the size of vessels of transport can only be increased within narrow limits, because the canals mostly communicate at low water with navigable rivers with a determined transverse section, the construction of two entirely distinct canals each for two boats, instead of one canal for three boats should be taken into consideration. Thus the security of the navigation would be increased in a manner much more favourable, than it would be by *one* canal for two or three boats. It must also be admitted that the extra expense of forming two canals instead of one would be compensated by an increase in the movement of transport, as a consequence of the placing of a larger number of industrial districts in communication with each other.

II. LEAST MEASURE OF DEPTH OF WATER UNDER THE KEEL OF A LOADED BOAT.

A sufficient distance between the keel of the boat and the bottom of the river is not of such real importance in the crossing of boats as the width of the canal at the plane of the greatest immersion of the boat. With a great depth of water the power of traction, which is above all necessary for a rapid working to screw-boats will be considerably lessened and consequently, the working expenses will be proportionately diminished.

For trains and boats navigating alone, which are of the largest dimensions permitted by the canal and working with screws, the distance between the keel of the boat and the bottom of the canal must be calculated in advance more liberally than for those worked by other means, for the bottom of the canal is agitated by the action of the screw and the working of the waves on the banks is stronger. The greater depth of water not only diminishes the traction required, but also increases the steering power, a point of great importance to trains, especially in the curves of the canal. With a sufficient depth of water, too, the action of the water behind the boats, which is so prejudicial to trains in crossing is lessened, so that inequalities in the bottom will not be so likely to cause a collision of trains, because there is space enough under the boats for the water streaming transversely, and in consequence the boats do not so easily escape the action of the rudder at time of crossing.

As *least* distances between the keel of the boat and the bottom of the canal, we may, failing exact scientific data, take for model the following values:

Table.

Tonnage in tons.	Least distance between keel of boat and bottom of canal in centimeters.	
	worked by screw.	worked otherwise.
200	40 cm.	30 cm.
400	50 „	35 „
600	60 „	40 „
800	70 „	45 „
1000	80 „	50 „

III. MINIMUM RADIUS FOR CURVES IN CANALS.

The determination of the smallest curve radius depends in the first place on the nature of the working at high speed. The larger the number of boats navigating in file, the more important it is that strong curves should be avoided.

But, on inland navigation canals it is not necessary to form lóng trains except under special circumstances.

This necessitates even with a moderate traffic the establishment of long train locks using a considerable quantity of water, or the parting of the train and the establishment in time of two locks side by side, so as to diminish the duration of the traject for single boats. The economy of traction power in the employment of trains on canals of narrow section is not so great as it is on wide rivers. By observing the rule laid down at the Vienna Congress „increase the width of the bottom in curves by twice the height of the arch, of which the span represents the greatest length of the boat", we cannot go *below a radius of* 500 *meters* for canals, which allow of a rapid navigation with at most two boats in file. In case it should not be possible to avoid a pronounced curve on the part of a canal with strongly consolidated banks, we would recommend that recourse be had, either to a widening of the bottom to a greater extent than indicated above, or to an increase of the transverse section of the water by steeper consolidated banks, thus obviating as much as possible the grounding of the boats in the curves.

IV. THE MOST PRACTICAL AND MOST PROFITABLE ARRANGEMENT AND COMPOSITION OF BANKS AND SLOPES.

Professor SCHLICHTING has given in his report to the Vth Congress in Paris, page 17, a short description and sketches of bank-dressing executed by way of trial on the Haneken Canal near Lingen in Hanover.

The trials described in the report were made with the object of determining which construction was the most suitable for the projected canal from Dortmund to the Ems.

According to what has been said above and following the opinion expressed by the reporters at the Paris Congress, it will scarcely be possible to find a consolidation which can be recommended in all circumstances. We will therefore, here, but briefly review the experiences made on the Haneken canal, and add a few general observations.

The part chosen for the study was four years ago made free from the influence of frost. Trials were made, also on numerous trips with a small steamer to determine more exactly the influence of the wash on the banks. The redressing of the banks with concrete and pieces of brick or with morton has relatively given the worst results, as it peeled off to a more or less extent near the water-line. The same must be said of the trials made with the application of a construction made of the hydraulic-lime of BECKUMER, the surprising want of resistance of which, may be ascribed in a great measure to the too limited duration of time allowed for its hardening before the frost set in. On the other hand scorified cement plates have resisted the action of frost in a most satisfactory manner.

On these plates no effect of frost has been observed near the water-line, notwithstanding, that in the last winter periods severe frosts have frequently occurred. The plates are 50 cm. wide, 1.25 m. long and 8 cm. thick.

They consist of a composition of scorified cement and sand in the proportion of one part of scorified cement to three parts of sand. Although, we may in all probability conclude from the experiments made up to the present that this material is capable of resisting for many years the influence of changes of temperature, it is still to be recommended that experiments in this direction be continued. Accordihg to the condition of the land in the districts through which the canal is cut, and according to its natural resources in wood or in stone, other modes of construction more convenient and less expensive may be taken into consideration.

1) *Conclusions from these experiments, and propositions for a practical consolidation.*

Taking the foregoing observations as a basis, a practical consolidation of banks must fulfil the following principal conditions:

a) The materials employed must above all be capable of resistance to frost, be of sufficient consistency and have as smooth a surface as possible.

b) The bank protection must follow projections and hollows without leaving any breaks or crevices; it must be composed of different parts and yet have as few joints as possible, as these favour the working of the waves on the material of the bed.

c) All must be so arranged that repairs can be easily effected, and as far as possible, independently of the influence of the weather and without removing any other part than the part damaged.

A dressing material of plates complies with these conditions and the only remaining question is to diminish as much as possible the expense of laying down these plates while retaining sufficient consistency and power of resistance to frost.

In the construction of the part of the canal taken as the field of experiments the expense of consolidation by means of artificially composed plates was less than the expense of other modes of consolidation, in which various stone materials were employed; and if the plates were manufactured in large quantities a still further reduction might be expected. If with regard to constructions already undertaken there should be question of covering the banks with a layer of concrete and to insure its durability by means of separate pieces at fixed distances, there would still remain the difficulty that the damaged parts could not easily be separated and would not be (as should be the case) independent of the influence of temperature; and above all that the establishment of all the dressing would be much more dependent on accidents, than it is when plates are employed (which can easily be tested by experiment before their application) and the hardening of which when properly applied may be counted upon independent of the influence of temperature.

There is, likewise, the further advantage that in the manufacture of these plates in large quantities hydraulic pressure can be used without any increase of expense, and this augments largely their power of resistance to changes of temperature.

Another advantage obtained by consolidation by means of plates is that for the washing of the bed and of places where the consolidation is not very fixed a new and convenient use of the plates is rendered possible. On the part of the canal experimented upon a good remedy against washing was found in the caulking of fissures with moss. The caulking with moss, which allows for expansion and shifting of the plates need not be applied between all the plates, but only at larger distances. When there are springs in the bed it is easy to deviate the pressure of the water by increasing the number of open joints. In order to obviate the washing out of the lower-bed consistent materials must be selected for its composition When the condition of the ground is particularly unfavourable a special under-bed of dry concrete should be applied.

We have now to consider the most suitable materials and the dimensions of which the plates should be composed. The question of price will decide the first point.

On the other hand the dimensions will be dependent on the slope of the plates. In any case it is advisable to avoid as far as possible horizontal joints in parts which are exposed to the wash of the waves and to the influence of temperature near the waterline. To obviate the necessity of plates of too large a size the consolidation of the banks should be divided in a consolidated foundation at a sufficient depth below the water-line, protected as far as possible against the action of frost and from expansion by heat, and another part, moveable and independent of this foundation and not at too great a slope.

The foundation may either in one piece without joints be made on the spot of dry concrete, or of separately placed blocks.

2). *Determination of suitable conditions of slope of plates.*

In the debates of former Congresses it was not found possible to form a decision as to the most practical slope in the consolidation of banks, for it is in most cases local conditions which must decide the point.

The consolidations applied to the banks of different canals show an extraordinary variety, not only with regard to form of construction and the materials employed, but also as to the slope given to the surface dressing of the banks. Notwithstanding that these differences are explained by the diversity of the object to be attained, it must be acknowledged that there exists at the present day great uncertainty concerning the best method of consolidation; and that the whole problem, at least as regards canals with a quick working, remains in the stage of more or less successful experiments.

Generally speaking the height of accumulated waves may be lessened by a correspondingly steeper incline in the consolidated part of the bank and the resistance offered to the movement of the water, which flows laterally under the bows of the boat at the time of crossing may be reduced to the smallest proportions for transverse sections of water differently limited but of the same capacity, by means of slopes made gradually steeper towards their summit.

On the contrary the wave formed at the stern of the boat loses its force sooner in flowing on to a bank of less slope and will thus facilitate, if only in a small degree, the progress of the boat. This, however, only applies where long boats are concerned, and on narrow canals, or trains which are directly influenced by the wash of the waves.

For the return of the water displaced by the keel of a passing boat it is of but little consequence whether the part of the consolidated bank near the water line has an incline more or less steep, for the transverse section of the body of water between the boat and the bank is not seriously influenced by the difference of slope on this part of the bank Besides, by removing the consolidation of the bank a little towards the towingpath, or, according to circumstances towards the waterline an arrangement may be found which will obviate the necessity of changing the transverse section and the return of the water. It must, also, be considered that very steep slopes require a stronger construction and that the influence of frost on a steep consolidation increases in an unfavourable degree. Experiments made with different slopes of plates have shown that a slope of about 1 : 1.25 to 1 : 1.5 generally answers all requirements. A less slope of 1 : 3 would needlessly increase their length and a steeper incline than 1 : 1.25 would frequently necessitate a greater consolidation of the lower bed. We can, therefore, not adhere to the opinion expressed by SCHLICHTING at the Paris Congress that a steep bank consolidation is to be preferred not only on account of the economy in expense of maintenance but above all in the interests of navigation.

3) *Suitable height for the consolidated part above, and depth below the waterline.*

Experiments which have been made have proved that with a slope within the limits of 1 : 3 up to 1 : 5 an average rising of the water of about 0.30 m. above the water-level ensues, whereas the lowering of the surface of the water below the water-line reaches generally a greater value, viz. about 0.40 m.

As the real speed of steam-tugs will be considerably less than that of the small steamer used for the experiments, we may suppose that the fluctuations of the waves produced by the steamer at the water-line will not on the average be greater than at the time of the experiments.

Trains of boats generally follow the central line of navigation, and are thus at some distance from the banks, so that the body of water displaced by the transverse half section of the keel of the boat finds a more favourable transverse section of flow. At the crossing of two boats the speed of progress decreases, and the speeds produced in the opposite direction tend to equalise the quantity of water displaced.

The depth of the foundation of the bank must be so chosen as to absolutely exclude all danger from the beating of the waves and to render very firm the part serving as support, for any injury to the foundation necessitates expensive repairs, which increase in an unprecedented manner the cost of maintenance. A later deepening of the consolidation would cause a great sacrifice of money and in some cases necessitate the removal of the pilework, on which, for economical reasons, the base of the construction is supported.

On the contrary, a later increase of the height of the banks above the water-line would present no difficulties in execution and the expense would not be much more than at the time of the first construction.

Unfortunately, experiments have not furnished any reliable data as to the effect of the depth of waves arising from the consolidation of the banks. In any case, it is always advisable to let the lower supporting body terminate in a slope as easy as possible in order that the descending wave may not reach the bed in front of the foundation but be turned aside.

The most simple course would be to give to the lower supporting body a rounded form, which with a manufactured construction can be effected without any appreciable increase of expense.

As least measure of the vertical distance from the consolidated base of the bank to the lowest water-line 0.8 m. should be taken. The height above the water, having regard to what we have just said, may be limited to 0.5 m., as an increase of height can easily be executed later on according to requirement.

4) *Position of consolidated banks towards the lower banks of canals.*

Experiments made with steamboats have proved in accordance with the debates at the Paris Congress that non-fortified slopes in direct connection with the base of a consolidated bank have a tendency to a level form, that is a slope of about 1 : 5. By the establishment of a berme below the water-line the section of the canal is in a way divided in two. (See the dotted line in fig. 7, Plate I.) The lower section must be sufficiently wide and deep to resist the influence of the working of the waves produced by the screws of the boats. The widened upper section causes then a favourable weakening of the working of the waves against the banks.

5) *Execution of other experiments.*

Considering the uncertainty which still remains with regard to the determination of the question as to how much and to what depth the waves caused by navigation work on the banks of canals, further experiments on longer distances and under different conditions of working are absolutely necessary.

For the better examination of the action of the working of the waves at different depth it is advisable that the base of the bank be established in advance at at least 1.0 m. below low water, and to change the height of the berme below the water.

By spreading coloured sand on the bank and establishing different inclines the action of the waves can be more exactly defined. In future researches the principal point will certainly be to establish conditions analagous to those which will prevail at the working. In this sense it will be well to take exact account of the influence of the wind on the movement of the waves.

FINAL OBSERVATIONS.

1) *The number of crossings of boats and the losses of time resulting from these crossings depend, the extent of the traffic being given, on the tonnage of the boats and their possible working speed. With a large traffic on a narrow section canal they increase in such a manner that the average working speed diminishes rapidly.*

2) *According to the data mentioned here in Chapter I it may be considered as proved that for principal canals with a large traffic — in accordance with the conclusions of the Vienna Congress — the normal transverse section of the water should be at least four times as large as the largest immersed transverse section of the boat. The increase of the transverse section of water to about five times the transverse section of the boat will likewise effect an economical advantage with respect to the capital engaged and to the diminution of the expenses of working and of maintenance.*

3) *In canals of rapid working it is indispensable to have for the crossing of boats ample width in the plane of the depth of the greatest immersion. At this depth may be recommended for boats of* 300 *tons a least width of double the greatest width of the boat* + 5.0 *m. and to increase this width by* 0.5 *m. per* 100 *tons additional tonnage.*

4) *In order to reduce the number of hindrances to navigation bridges over the canal should by preference be built without central piles. Likewise, the width of the canal under the bridges in the plane of the greatest depth of immersion of boats should be at least equal to the width of the canal in its free part at the same depth of water.*

5) *It is desirable that the examination of the question of resistance to traction on canals be completed by determining the losses of speed at crossings for different transverse sections of canal, and for various kinds of working.*

6) *The least measure of depth of water under loaded boats should be fixed according to the greatest tonnage and according to the kind of working. For the different tonnages and kinds of working reference may be made to the table given in Chapter II.*

7) *The diminution of the number and the extent of curves in the forming of new large canals for a quick working is of the greatest importance. As permissible limit of a curve may be taken a minimum radius of 500 metres.*

8) *For the protection of the banks of the canal against the working of the waves may be recommended the establishment of a berme of sufficient width (at least* 1.5 *m.) and at a suitable depth (not less than* 0.8 *m.) below the line of the lowest water-level, as well as the consolidation of the bank above the berme by natural or artificial stone materials having their surfaces as smooth as possible and very few joints. The angle of the incline between the face of the bank and the horizontal line should be between* 30 *and* 40 *degrees.*

Translated by G. J. Rowland.

Inschriften der Zeichnungen.	Inscription des Planches.	Description of the Plates.
BLATT 1.	PLANCHE 1.	PLATE 1.
Fig. 1.	Fig. 1.	Fig. 1.
Darstellung der Geschwindigkeitsänderungen während der Fahrt des Schiffes.	Changements de vitesse pendant le trajet.	Variations in speed on the journey.
Fig. 2.	Fig. 2.	Fig. 2.
Schleuse.	Ecluse.	Dock.
Darstellung der Schiffskreuzungen in einer Haltung.	Tableau des croisements des bateaux dans un même bief.	Table showing the crossing of boats in one reach.
Fig. 3.	Fig. 3.	Fig. 3.
Kanal.	Canal.	Canal.
Darstellung der Geschwindigkeitsänderungen bei einer Kreuzung.	Changements de vitesse pendant le croisement de deux bateaux.	Variations in speed during the crossing of two boats.
Fig. 4.	Fig. 4.	Fig. 4.
Kanalprofil von 14 m. Sohlenbreite.	Profil d'un canal ayant 14 m. de largeur au fond.	Section of a canal 14 m. wide at the bottom.
Fig. 5.	Fig. 5.	Fig. 5.
Enges Profil.	Profil étroit.	Narrow section.
Weites Profil.	Profil large.	Wide section.
Darstellung der Geschwindigkeitsänderungen bei Kreuzungen im engen und weiten Profil.	Changements de vitesse pendant les croisements dans des profils étroits et des profils larges.	Variations in speed during crossings in narrow and wide sections.
Fig. 6.	Fig. 6.	Fig. 6.
Vertheilung des Verkehrs.	Répartition du trafic.	Distribution of traffic.
Durchschnitt in 270 Tagen.	Trafic moyen en 270 jours.	Average traffic in 270 days.
Fig. 7.	Fig. 7.	Fig. 7.
H. W.	H. E. (hautes eaux).	H. W. (high water).
N. W.	B. E. (basses „).	L. W. (low „).
Uferbefestigung durch Platten.	Consolidation au moyen de plaques.	Consolidation of the banks by means of stone flags.
BLATT 2.	PLANCHE 2.	PLATE 2.
Fig. 1.	Fig. 1.	Fig. 1.
Darstellung der Haltungseinheiten.	Tableau des unités de bief.	Table of reach units.
Abstand der Schiffe in der Haltung in derselben Fahrtrichtung bei regelmässigem Vollbetrieb.	Distance des bateaux voyageant dans une même direction, dans un bief avec trafic régulier maximum.	Distance between boats travelling in the same direction on a reach with regular maximum traffic.

Weites Profil.	Profil large.	Wide section.
Enges Profil.	Profil étroit.	Narrow section.
Für verschiedene Geschwindigkeiten und Schleusungszeiten im engen und erweiterten Profil.	Pour différentes vitesses et durées d'éclusage dans des profils étroits et élargis.	For different speeds and length of time spent in locks in wide and narrow sections.
Dauer der Doppelschleusung.	Durée du double éclusage.	Length of time spent in double locks.
Verkehrsgrösse in Millionen Tonnen bezogen auf wachsende Schleusungszeiten.	Trafic en millions de tonnes calculé pour des durées croissantes d'éclusage.	Traffic in millions of tons calculated for the increasing length of time spent in the locks.
Maasstab.	Echelle.	Scale.
FIG. 2.	FIG. 2.	FIG. 2.
Weites Profil.	Profil large.	Wide section.
Enges Profil.	Profil étroit.	Narrow section.
Schiffsweg in der Sekunde im engen und erweiterten Profil für wachsende Schleusungszeiten.	Parcours du bateau par seconde dans des profils étroits et élargis, pour des durées croissantes d'éclusage.	Distance travelled per second by the boat in narrow and wide sections for the increasing length of time spent in the locks.
Dauer der Doppelschleusung.	Durée du double éclusage.	Length of time in double locks.
Ersparniss an Weg in der Sekunde durch Erweiterung des Profils.	Economie de parcours par seconde réalisée par l'élargissement du profil.	Saving of distance per second consequent upon the increased width of the section.
Maasstab.	Echelle.	Scale.
BLATT 3.	PLANCHE 3.	PLATE 3.
Darstellung der jährlichen Ersparnisse an den Betriebskosten der Schifffahrt für das Kilometer Kanallänge durch Erweiterung des Profils.	Tableau des économies réalisées, par an et par kilomètre, sur les frais d'exploitation de la navigation, par l'élargissement du profil.	Table showing the saving realised per annum per kilometre in the working expenses of navigation by the increased width of the section.
Jährliche Verkehrsgrösse in Tonnen.	Trafic annuel en tonnes.	Annual traffic in tons.
Reine Betriebskosten incl. Verzinsung.	Frais d'exploitation avec intérêts.	Working expenses with interest.
Ersparniss an Weg.	Economie de parcours.	Saving in distance.
Maasstab für die Ersparnisse.	Echelle des économies.	Scale showing savings realised.
Maasstab für die Tonnenzahl.	Echelle du tonnage.	Scale of tonnage.
Ersparniss für	Economie pour	Saving for . . . .
BLATT 4.	PLANCHE 4.	PLATE 4.
Zahl der Schiffe.	Nombre des bateaux.	Number of boats.
Zunahme der Zahl von Schiffen der deutschen Rheinflotte mit einer Tragfähigkeit von über 500 Tonnen, geordnet nach den Jahren der Erbauung für Gruppen mit verschiedener Tragfähigkeit.	Tableau de l'augmentation des bateaux allemands sur le Rhin, chargeant plus de 500 tonnes, classés par ordre de la date de la construction, pour des groupes de différent tonnage.	Table showing the increase in German boats on the Rhine, of more than 500 tons burden, classed in order of date of building, for groups of different tonnage.
Nach einem Auszuge aus dem Rheinschiffs-Register VII. Ausgabe 1890, und den 12 Nachträgen vom Jahre 1891.	D'après le „Rheinschiffs-Register", N°. VII, édition de 1890, et les 12 suppléments de 1891.	According to the „Rheinschiffs-Register" N°. VII, edition of 1890 and the 12 supplements of 1891.

Von der Zusammenstellung sind ausgeschlossen diejenigen Schiffe, deren Erbauungsjahr nicht bekannt ist, in Ganzen 22 Schiffe.

Zusammenstellung.

Schiffe mit durchschnittl.	600	T. Tragfähigkeit i. G.	93
	700	„ „ „ „	73
	800	„ „ „ „	105
	900	„ „ „ „	46
	1000	„ „ u. mehr „ „	81
		Summa . .	398

Jahr der Erbauung.

BLATT 5.

Schiffe.

Anzahl der Schiffe.

Tragfähigkeit der Schiffe.

Zusammenstellung der Anzahl und Tragfähigkeit der in dem Rheinschiffs-Register von Jahre 1890 und den 14 Nachträgen bis März 1892 aufgeführten Schiffe der Rheinflotte.

Maasstab.

Ne sont pas compris dans cette énumeration les bateaux dont l'année de construction n'est pas connue, soit 22 bateaux.

Enumération.

Bateaux d'un tonnage moyen de	600	tonnes.	93
	700	„	73
	800	„	105
	900	„	46
	1000	„ et plus . . .	81
		Total . . .	398

Année de construction.

PLANCHE 5.

Bateaux.

Nombre des bateaux.

Tonnage des bateaux.

Enumération du nombre et du tonnage des bateaux naviguant sur le Rhin et indiqués dans le „Rheinschiffs-Register" de 1890 et dans les 14 suppléments parus jusqu'au mars 1892.

Echelle.

The boats whose date of building is not known are not included in this list, in all some 22 boats.

List.

Boats of an average tonnage of	600	tons	93
	700	„	73
	800	„	105
	900	„	46
	1000	„ . and over .	81
		Total . . .	398

Year of building.

PLATE 5.

Boats.

Number of boats.

Tonnage of boats.

List of number and tonnage of boats navigating on the Rhine and noted in the „Rheinschiffs-Register of 1890 and in the 14 supplements brought out up to March 1892.

Scale.

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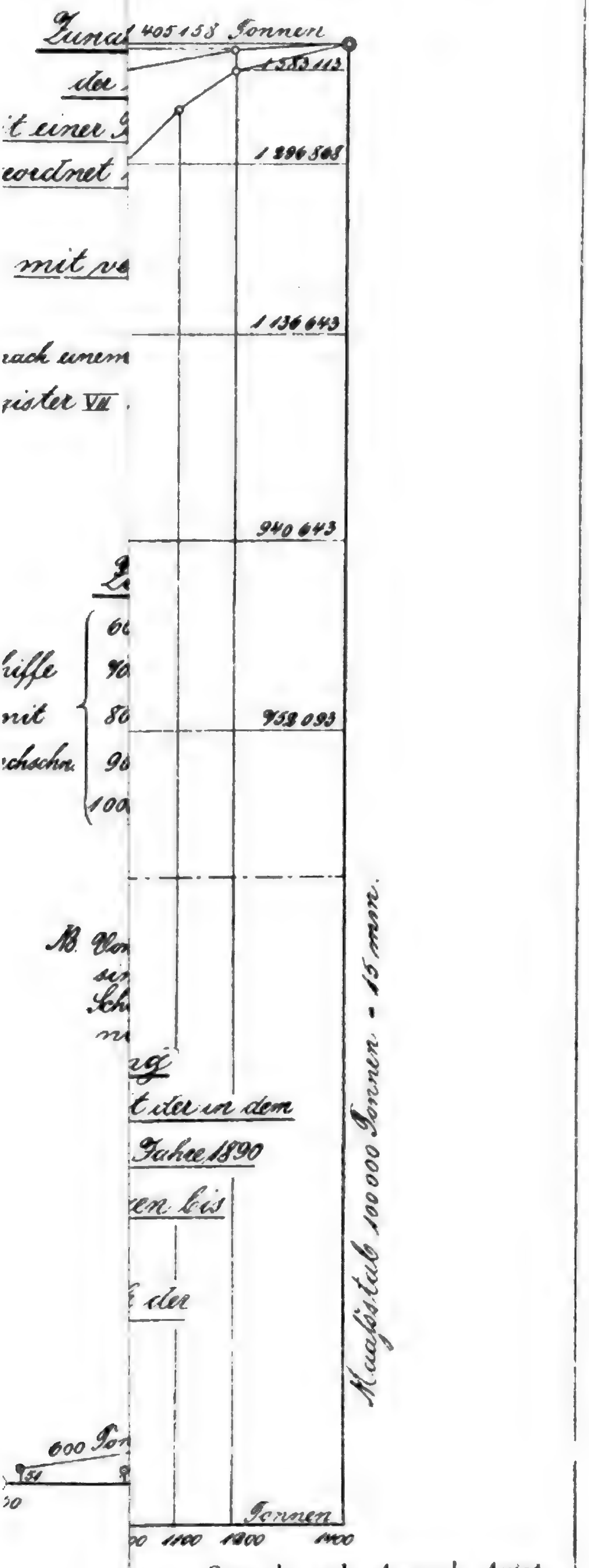
Blatt 5.



Steendr. v/h. Amand, Amst.

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VI^th INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

1st QUESTION.

CONSTRUCTION
OF
Navigation Canals affording operation at high speed.

BY

M. DEROME,
Ingénieur en chef des ponts et chaussées à Compiègne.

THE HAGUE,
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VIth International Inland Navigation Congress.

THE HAGUE 1894.

Construction of navigation canals affording operation at high speed.

BY

M. DEROME.

Ingénieur en chef des ponts et chaussées à Compiègne.

We propose to consider in the present report the arrangements, which could be most usefully applied on inland navigation canals, with the view of allowing boats frequenting them to accelerate so much as possible their speed.

This question comprises several points, which we will examine successively.

I. FORM AND DIMENSIONS OF THE NORMAL SECTION OF CANALS.

The official programme puts in the first place the following question: „determine the flowing section of a canal which will allow a boat of a given immerged section to realise a desired speed with the least effort of traction."

This gives rise to an important observation. A boat tugged on a sheet of water, which is on all sides undefined at a uniform rate of speed has to contend with a certain resistance of the water. On a canal of small section the resistance to be overcome in order to attain the same speed will be considerably greater.

This resistance diminishes progressively when the section of the canal increases continuously, and tends towards a certain limit, which, evidently, corresponds to the resistance suffered by the boat on an undefined sheet of water.

The problem is thus reduced to the determination for a boat of a given immerged section and a given speed, of a wet profile which may be practically assimilated to an undefined sheet of water. But, leaving out of account certain exceptional cases, such a profile could only be realised at very great expense, so that the solution of the problem would have an interest purely theoretical.

Therefore, it would be, in our opinion, preferable to endeavour to find a profile corresponding, not to the least effort of traction, but to a given effort of traction.

The two problems thus posed can, however, only be solved by means of „the relations which exist between speed, effort of traction and immerged section of the boat, on the one part, and the surface and form of the wet section of canals on the other".

The Vth Congress expressed the wish that experiments should be made in different countries with the view of determining these relations.

As regards France Mr. de Mas has complied with this expressed wish by continuing the researches on the subject begun by him in 1890.

These researches have not touched upon a number of points, which have still to be elucidated. Nevertheless, the results obtained point to very important conclusions, which we must take into consideration.

EXPERIMENTS OF Mr. DE MAS.

Resistance of boats to traction on an undefined sheet of water.

For the purpose of his researches Mr. de Mas has confined and established very ingenious apparata, which indicate at any instant with all desirable accuracy the proportionate speed of the boats in relation to the water, as well as the effort of traction corresponding to this speed.

He first operated on the Seine, above the weir of Port-à-l'Anglais, in a section where the course of the river runs in an almost straight line and has a witdh of 135 meters, an average depth of nearly 4 meters and a wet section of at least 525 square meters.

The dimensions of this profile may as regards the boats tried be considered as undefined, for these boats have as a rule not more than 5 meters of width with 1.89 m. of depth.

The experiments were made with different boats selected from the types mostly in use on the French canals, viz. Flemish péniches, toues of the Saône, flûtes and margotats of the Upper Seine, Prussian boats etc.

In accordance with the researches in the last century (1), it is generally admitted that the resistance of these boats tugged at a moderate speed on an undefined sheet of water is suitably represented by the formula

$$R = K B V^2$$

in which B the immerged secton amidships, V the speed and K a constant coefficient for a boat of determined form.

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(1) In France by Bossut, d'Alembert, Condorcet and Dubuat; in England by Colonel Beaufoy.

The experiments of Mr. DE MAS have shown that the various elements, on which resistance to traction depends are not connected between themselves by this proportion or by any other of the same form. In order to prove this it is only necessary to deduce from the results of the following facts.

1°. *For a boat worked at given speed, the resistance to traction is not proportionate to the immerged section B.*

This fact is shown by the following tables, which apply to a flûte of the Upper Seine tried at the successive depths of 1.00 m., 1.30 m. and 1.60 m. (1).

(*a*). **Dimensions of the immerged part of the boat.**

Depth. t.	Length. L.	Average width amidships l.	Immerged section amidships.	
			absolute B = lt.	relative.
1.00 m.	37.54 m.	5.02 m.	5.02 mq.	1.00
1.30 „	37.74 „	5.02 „	6.53 „	1.30
1.60 „	37.99 „	5.02 „	8.03 „	1.60

(*b*). **Resistance of the boat traction.**

Speed per second.	Absolute resistances at a depth of			Relative resistances at a depth of		
	1.00 m.	1.30 m.	1.60 m.	1.00 m.	1.30 m.	1.60 m.
0.50 m.	39 kil.	44 kil.	54 kil.	1.00	1.13	1.38
1.00 „	129 „	143 „	162 „	1.00	1.11	1.26
1.50 „	280 „	315 „	355 „	1.00	1.13	1.27
2.00 „	502 „	579 „	664 „	1.00	1.15	1.32
2.50 „	805 „	953 „	1119 „	1.00	1.18	1.39

These tables show that for one same speed the resistance increases less quickly than the immerged section B.

2°. *For a boat immerged to a given quantity the resistance to traction is not proportionate to the square of the speed.*

This result may be deduced from the figures shown in the table (b); it appears, however, preferable that it should be determined by means of experiments made on boats of different types, the elements of which are grouped in the following tables (2).

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(1) These tables are extracts from «Recherches expérimentales sur la Batellerie» second number, pages 40 and 41.

(2) These elements are extracted from the works of Mr. DE MAS, first number, page 36 and second number pages 66^1 and 66^2.

(*c*) Dimensions of the immerged part of boats.

	Length. L.	Average width amidships. l.	Depth. t.	Total Displacement. D.	Immerged section amidships. B.
Flemish péniche . . .	38.19 m.	5.00 m.	1.81 m.	342 T.	9.05 mq.
Toue of the Saône . . .	36.08 "	5.02 "	1.36 "	240 "	6.83 "
Flûte of the Upper-Seine .	37.44 "	5.02 "	1.47 "	260 "	7.38 "
Prussian boat	34.10 "	4.91 "	1.30 "	203 "	6.38 "

(*d*). Resistance of boats to traction.

Speed per second.	Péniche.	Toue.	Flûte.	Prussian boat.
0.50	115 kil.	35 kil.	76 kil.	22 kil.
1.00	340 "	100 "	198 "	80 "
1.50	772 "	235 "	360 "	185 "
2.00	1462 "	475 "	675 "	349 "
2.50	" "	795 "	1110 "	582 "

If we take as unit the resistance to traction corresponding to the speed of 1 meter per second the preceding table is transformed as follows:

Speed per second.	Relative resistances.			
	Péniche.	Toue.	Flûte.	Prussian boat.
0.50	0.34	0.35	0.38	0.28
1.00	1.00	1.00	1.00	1.00
1.50	2.27	2.35	1.82	2.31
2.00	4.30	4.75	3.41	4.36
2.50	4.30	7.95	5.61	7.28

It results from this last table that with the exception of the Flûte, the resistance increases more quickly than the square of the speed and that the deviation varies:

For a speed of 0.50 m. per second from 12 to 40 °/₀.
" " " " 1.50 " " " " 1 " 4 "
" " " " 2.00 " " " " 8 " 19 "
" " " " 2.50 " " " " 16 " 27 "

3⁰. *For a given boat the proportion* $\frac{R}{B\,V^2}$, *sometimes called the coefficient of resistance to traction is not independent of the speed.*

This proportion varies according to the figures shown in the table (*c*) and (*d*) as follows:

Speed per Second.	Values of the proportion $\frac{R}{B\,V^2}$			
	Péniche.	Toue.	Flûte.	Prussian boat.
0.50	50.8	20.5	41.2	13.8
1.00	37.6	14.6	26.8	12.5
1.50	37.9	15.3	21.7	12.9
2.00	40.4	17.4	22.9	13.7
2.50	40.4	18.6	24.1	14.6

Examination of this table shows that the proportion $\frac{R}{B\,V^2}$ passes through a minimum for the speeds from 1.00 to 1.50 m. and that it is considerably larger for the speed of 0.50 m., than for those of 2 m. and above.

4°. *For a given speed and a given depth the resistance of a boat to traction varies considerably accordingly as the wet surface is more or less smooth.*

This fact is shown by experiments made on the flûte referred to in table (*a*); the resistance at different speeds, at a depth of 1.60 m. has been repeatedly measured, the wetted surface having been previously treated in the following ways:

a) carefully rubbed with sand until the wood was brought back into its natural state;

b) covered with oilcloth to a height of 1.26 m. above the water-line;

c) entirely covered with oil cloth.

The resistances measured under these conditions were the following (1):

Speeds.	Resistances to traction.			Differences between the resistances (*a*) and (*c*).	
	Wetted surface brought to natural state. *a*)	Wetted surface covered with oil cloth to a height of 1.26 m. *b*)	Wetted surface entirely covered with oil cloth. *c*)	absolute.	relative.
0.50	54	46	28	26	0.48
1.00	162	142	105	57	0.35
1.50	355	308	250	105	0.30
2.00	664	558	480	184	0.28
2.50	1119	906	812	307	0.27

---

(1) The figures shown in the table are taken from the work of Mr. DE MAS, second number pages 45 and 48.

The above table shows that the substitution of a perfectly smooth surface (oilcloth) for the rough surface of the hull (with the wood brought into its natural state) is sufficient to reduce the resistance to traction in a variable proportion of 27 to 48 $^{0}/_{0}$.

5°. *For boats of the same form and otherwise of equal condition, the resistance to traction is entirely independent of the length of the boat.*

This fact has been established by measuring the resistance at a depth of 1.60 m. of three flûtes, of which the forms at the fore and the aft parts were as nearly identical as possible, and of which the depth amidships was uniformly 5.02 m., but which showed at the water-line the respective lengths of 37.99 m., 30.03 m. and 20.55 m.

This experiment gave the following results (1):

	Resistance for the following speeds.				
	0.50	1.00	1.50	2.00	2.50
Boat 37.99 m. in length.	54 kil.	162 kil.	355 kil.	664 kil.	1119 kil.
„ 30.03 „ „ „	51	160	355	665	1120
„ 20.55 „ „ „	51	160	355	665	1120

The figures corresponding to one same speed agree together in a singular manner. They establish an important fact, which seems to be in contradiction with the sufficiently confirmed influence of the wetted surface of boats on their resistance to traction.

This contradiction is of course only apparent; the fact in question must be considered as the result of complex actions, of which the laws have still to be discovered.

Nearly connected with the preceding facts, this last does not leave any doubt as regards the considerable difficulties, which have still to be overcome for the complete solution of the problem of the resistance of boats tugged on an undefined sheet of water.

Resistance of a boat to traction on a canal.

In the second instance M^{r} de Mas has studied the resistance of boats on a canal and has selected for the field of his experiments a reach of the Burgundy canal, which has on a length of 1600 meters a straight section and a remarkably regular profile. The wetted surface of this profile varies from 29.13 mq. to 29.78 mq. with an average of 29.53 mq.

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(1) These results are extracts from the work of Mr. de Mas, second number page 49.

He has tried on this reach the different types of boats with which he had experimented on the Seine at speeds increasing from 0.25 m. and by degrees of 0.25 m., but only up to 1.25 m., and has found that, all other factors being equal, *the resistance to traction is independent of the length of the boats*; at least, in the limits and under the conditions in which the experiments have been made.

On the other hand Mr. DE MAS has obtained the following results (1) for boats of the types named in tables (*c*) and (*d*).

(*e*) Dimensions of the immerged part of boats.

	Lengths at a depth of			Widths amidships.	Total displacement at a depth of			Proportion of the wet sections of canal and of boat at a depth of		
	1.00	1.30	1.60		1.00	1.30	1.60	1.00	1.30	1.60
Flemish péniche	38.17 M.	38.25 M.	38.25 M.	5.03 M	190 T.	247 T.	304 T.	5.87	4.51	3.67
Toue of the Saône	37.42 „	37.68 „	37.92 „	5.02 „	184 „	241 „	297 „	5.88	4.52	3.68
Flûte of the Upper Seine .	38.14 „	38.34 „	38.39 „	5.02 „	185 „	242 „	297 „	5.88	4.52	3.68
Prussian boat	33.70 „	34.10 „	„	4.91 „	161 „	203 „	„	6.01	4.62	„

(*f*) Resistances of boats to traction.

Speeds per second.	Depth of 1.00 m.				Depth of 1.30 m.				Depth of 1.60 m.		
	Péniche.	Toue.	Flûte.	Prussian boat.	Péniche.	Toue.	Flûte.	Prussian boat.	Péniche.	Toue.	Flûte.
0.25	22	16	16	13	33	22	23	17	43	32	33
0.50	73	46	50	38	114	68	76	54	172	109	117
0.75	163	100	112	81	256	150	173	119	415	249	271
1.00	296	178	203	145	469	272	320	215	860	463	506
1.25	510	300	350	249	807	469	561	370	1687	811	892

These results allow the possibility of controlling the formulae adopted for the determination of the resistance of boats to traction on a canal.

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(1) The figures shown in tables (*e*) and (*f*) are taken from the third number of the work of Mr. DE MAS.

Among these formulae, the following are mostly employed.

$$R = K B V^2 \frac{1}{n+2}$$

$$\text{and } R = K B V^2 \left(\frac{n}{n-1}\right)^2$$

in which n designates the proportion of the wet section C of the profile of the canal to the immerged section of the boat $\left(n = \frac{C}{B}\right)$.

The first formula was established by Dubuat in the last century and since applied by d'Aubuisson to the calculation of the resistance of boats on the Midi Canal.

The second is deduced from the formula $R = K B V^2$ with reference to an indefinite space, substituting for the absolute speed of the boat, its relative speed in proportion to the water displaced under the hypothesis that it would pass from the fore to the aft part of the boat with a uniform speed by the narrowed section C—B. (1)

Thus, the figures of tables (*e*) and (*f*) show for traction on canals facts analogous to those relating to tugging on an indefinite sheet of water.

1°. *For a boat moved at a given speed the resistance to traction is not proportionate either to* $\frac{B}{n+2}$ *or to* $B\frac{n^2}{(n-1)^2}$.

2°. *For a boat immerged to a given quantity in a canal of a constant wet section, the resistance to traction is not in proportion to the square of the speed.*

3°. *For a given boat the proportion* $\frac{R(n+2)}{B V^2}$ *and* $\frac{R(n-1)^2}{B V^2 n^2}$ *are neither one or the other independent of the speed.*

Therefore, the two above formulae can only give wrong results.

The figures given in the tables (*e*) and (*f*) also show to be unreliable a third formula proposed by an American engineer Mr. Sweet, founded on experiments made in 1878 in the Eric canal by means of a boat 29.50 m. in length and 5.37 m, in width, with a total displacement of 271 cubic meters at a depth of 1.83 m. (2).

This boat was firstly tugged in a reach with 2.135 m. of depth at speeds of 0.567 m., 0.825 m. and 0.872 m. per second; secondly, in a reach with 2.45 m. of depth at speeds of 0.701 m. and of 0.932 m. The proportion n was equal to 4.28 in the first case and to 5.00 in the second.

---

(1) This relative speed would be in fact $V + \frac{B V}{C-B} = V + \frac{V}{n-1} = V\frac{n}{n-1}$

(2) Report of Professor Schlichting to the Vienna Congress, 1886.

Mr. Sweet has found that the resistances observed under these conditions agree perceptibly with the figures given by the formula

$$R\frac{5.41\ S\ V^2}{n-0.597}$$

in which S is the wet surface of the boat (1).

The application of this formula to the boats forming the object of tables (*e*) and (*f*) gives entirely different results to those obtained by Mr. de Mas, as is clearly shown by the following table, which is for a depth of 1.60 m.

Speeds per second.	Péniche.		Toue.		Flûte.	
	Resistances observed.	Resistances calculated.	Resistances observed.	Resistances calculated.	Resistances observed.	Resistances calculated.
0.25	43 k.	36 k.	32 k.	36 k.	33 k.	36 k.
0.50	172	146	109	145	117	144
0.75	415	328	249	327	271	323
1.00	860	583	463	582	506	575
1.25	1687	911	811	909	892	898

This observation shows to what mistakes we become liable by generalising the use of formulae, which have been established on the results of insufficient experiments, or restricted within too narrow limits.

It would, also, be premature, as yet, to endeavour to draw conclusions from the researches of Mr. de Mas on canals, as to the relations between the resistance of boats and the various elements, which influence this resistance.

Up to the present these experiments have only been applied to the traction of boats at different depths in a canal of a determined section. Mr. de Mas is now completing them by the study of the resistance of similar boats immerged to a given quantity in canals of various sections. When this study is terminated, the total results obtained since 1890 will have to be collected and practical formulae compiled. Only then, will it be possible to attempt with any prospect of success the solution of the double problem laid down at the commencement of this report.

Under these circumstances we will confine ourselves to pointing out briefly the improvements which it is in our opinion desirable to apply to the arrangements and mode of working of existing French canals with a view to the acceleration of transports.

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(1) According to Professor Schlichting the deviation between the resistances observed varies from 2.5 to 7 pCt.

The wet surface S comprises the entire circumference of the boat below the water-line, including the fore and after parts.

IMPROVEMENTS TO BE EFFECTED IN THE ARRANGEMENTS AND MANNER OF WORKING OF CANALS.

We will indicate successively the improvements desirable with regard to:

The way and the artificial works.

The plant in the harbours.

The traction of boats and the plant for inland navigation.

Improvement of the way and the artificial works.

The French canals which depend on the principal navigation ways have as minimum in the flowing sections a bottom width of 10 meters and a draft of water of 2 meters with banks generally inclined at 3 of base for 2 of height and a wet section $C = 26$ square meters.

This is among others the present profile of the canal from the Marne to the Rhine.

These canals are navigated by boats of 5 meters in width and 1.80 m. of depth, of which the immerged section $B = 9$ square meters. The proportion $n = \frac{C}{B}$ is thus equal to 2.89.

Many of these canals, among others the one from the Oise to the Aisne have with a bottom width of 10 meters, a draft of water of 2.20 m., which gives $C = 29.26$ sq.m. and $n = 3.25$.

Others, as the Escaut canal has a bottom width of 11 meters with a depth of 2.20 m., by which C becomes 31.46 sq.m. and n 3.50.

Finally, there are others, as the St. Quentin canal measuring 12 meters at bottom with a depth of 2.20 m. Their wet section reaches 33.66 sq.m. and the proportion n amounts to 3.74.

It is shown in practice that with an equal speed the towing of Flemish péniches at a depth of 1.80 m. (1) is very fatigueing for horses on the canal from the Marne to the Rhine, less so on the canal from the Oise to the Aisne, rather easy on the Escaut canal and comparatively easy in the St. Quentin canal.

The successive increase in the wet section C and of the proportion $n = \frac{C}{B}$ thus give rise at equal speed to considerable reductions in the resistance of the péniches to traction.

These reductions, it is true, are not of sufficient importance to exercise any perceptible influence on the speed of the boats, as is shown by the figures in the table (*f*); they contribute, however, very much to the acceleration of transports; for the horses being less fatigued do not slacken their pace and make longer journeys.

Therefore, a considerable advantage would be obtained, by applying to other canals the same type of profile as on the St. Quentin canal, or, at least a type as near to it as is possible without incurring exaggerated expense.

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(1) Boats of this type figure in the proportion of 80 to 90 pCt. in the general account of the craft frequenting the canals of the northern and eastern districts of France.

In cases where a new canal destined for a considerable traffic is to be constructed, it might, perhaps, be advisable to allow a bottom width of 15 metres, permitting when necessary the crossing of three boats, if this width could be obtained without too much expense.

With a draft of water of 2.20 m. the wet section C would thus be carried to 40.26 sqm. and the proportion *n* to 4.47 m.; the result would be a certain increase of speed to boats, which may, apparently, be estimated at 8 or 10 pCt. as far as péniches are concerned.

The augmention of the draft of water would also have the effect of increasing the wet section, as well as the proportion *n*; but experience teaches us that above a certain depth the increase thus obtained reduces only in a limited measure the resistance of the boats to traction.

Nevertheless, it is of importance that the normal draft of water of 2.20 m. be never much diminished by the settling of mud; and as such deposits cannot be removed at the same rate as they are produced the reaches should be deepened by about twenty centimetres, so that the deposit may accumulate on the bottom a more or less longer time without causing inconvenience.

On the other hand the French canals have in many places narrow passages where the wet section is considerably less than that of the normal profile.

Experience teaches us that these passages delay the progress of boats, cause impediment and hinder in a most serious manner the regularity of working, especially when they are so narrow that two péniches cannot cross in them.

In the interest of the acceleration of transport it would be advisable to do away with all these passages and to establish everywhere the normal section, where this can be effected without extraordinary expense; and this scarcely excludes locks, tunnels and long cuttings. The employment of iron and steel allows at the present day of the construction without difficulty of bridges of a sufficient reach to span canals wide enough to pass two rows of boats, and the tow paths, — as well as of moveable bridges with central columns the opening of which gives at the same time two navigable passages of 6 to 7 meters in width. On the French canals the passing of the locks is frequently a cause of considerable loss of time to the boats. It is possible to remedy this, to a great extent by improvements, of which the following may form a programme.

a) Bring the height of water on the mitre-sill from 2.20 m. to 2.40 m. in locks the widths of which do not much exceed 5.20 m., in order to facilitate the entering and the leaving of boats.

b) Adopt for the gates a system of construction, which will allow of each wing being rapidly opened and closed (1).

c) Increase the number of openings for filling and emptying the chamber of the lock in such way that they may be used successively and as required (2).

d) Establish above and below the locks at 15 to 20 meters from each head, mooring places, where the boats can await their turns for passing (3).

e) Allow for towing-paths under bridges constructed on the „murs de fuite" of these works.

These different improvements give excellent results on the St. Quentin canal; they allow of the passage of 5 to 6 boats per hour through the locks of this navigable way (4).

It would, evidently, be of great advantage to apply them on other canals of large traffic in order to accelerate the rate of speed of transport.

Improvement of the plant in the harbours.

Most of the harbours situated on the French canals are totally unprovided with suitable plant.

Therefore, the loading of a boat of less than 300 tons often takes 6 to 8 days, where as with the aid of proper machines the same work could be done in 1 or 2 days; the same remark applies in every way to discharging.

This state of things evidently delays the dispatch and delivery of goods and causes an accumulation of goods at certain places at periods when navigation is most active.

Many loaded boats suffer delays of several weeks on this account, being obliged to remain in the reaches, where they are a hindrance to navigation, while at other places there is a want of boats for the dispatch of urgent goods. Suitable plant in harbours is, thus, of the greatest importance to the acceleration of transport.

But, in our opinion the task of developing such plant should be incumbent on private parties, or at least on certain public bodies, such as the Chambers of Commerce.

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(1) The duration of the working of a wing may be reduced to 30 or 40 seconds without the employment of any special mechanism.

(2) The filling of the chamber between the gates of a lock of 5.20 m. in width, of 38.50 m. in length and of 2.50 m. to 3.00 m. of fall may under normal conditions be effected in less than 2 minutes.

(3) These mooring places are not required when the locks are established on one side of the bed of water instead of in the middle of the canal.

(4) The annual traffic on the St. Quentin canal amounts to an average of 3500000 tons and on some canals which are exceptionally frequented it reaches 3800000 tons.

Improvement of the traction of boats.

On the canals of the North and the East of France boats are almost exclusively drawn by horses. On most of the canals the service is freely exercised, without other regulations than those which may result from the greater or less activity of demand and supply.

On some of the navigable ways, however, there are regular services of traction by horses; for example, on the canal from the Sambre to the lateral Oise canal. These services are purely private undertakings which contract with the navigators in their lest interests.

On the other hand the administration has organised on the line from Belgium towards Paris between Condé sur Escaut and Chauny a towage service conceded by public adjudication to contractors, who work it according to the conditions of a rate of charges confirmed by decree and according to a fixed tariff. This service is obligatory for loaded boats, with the exception of those which have their own steam power, and is at the choice of empty boats.

It contributes greatly to the securance of regularity and rapidity in transport and appears to us, in the present state of things absolutely indispensable on the navigable ways which it serves with regard to the exceptional importance of the line from Belgium to Paris.

The establishment of a service more or less analogous would, in our opinion, afford great advantages, on much frequented canals where no private traction service exists.

The employment of steam engines for the propulsion or traction of boats has up to the present had but a very limited developement on the canals of the above named district. There are about thirty cargo steamers, performing a service more or less regular between Paris and the principal towns of the north and the east.

There are four steam tug services, which work certain special passages generally in one direction only. The running of the cargo boats is naturally rapid, but it is comparitely dear; they can, therefore, only carry goods of a rather high value.

Towage in train is of great service on the points where it is now applied; but we consider that it might be profitably employed on other points, with the exception of reaches of exceptional length.

On the other hand, traction of single boats by steam is of capital importance for the acceleration of transports. Numerous experiments have been made in this respect, but there is at present not a single service of this kind working in France.

Improvement of plant for inland navigation.

The experiments of Mr. de Mas have brought to light an important fact, viz., the remarkable difference existing between the resistances to traction of the various types of boats in use on the French canals, under same conditions of speed and of wet section amidships.

This difference is, especially, considerable when the boats are tugged on an indefinite sheet of water. Still, it is very perceptible when the boats navigate a canal.

Table (*f*) gives in this last case for the resistance to traction of a péniche and a toue of the same length at the floating line and the same width amidships the following figures.

	Depth of 1.30 m.		Depth of 1.60 m.	
	Speed of 0.50.	Speed of 0.75.	Speed of 0.50.	Speed of 0.75.
Péniche	114 k.	256 k.	172 k.	415 k
Toue of the Saône .	68	150	109	249
Difference	46	106	63	166
Thus . . .	40 °/₀	41 °/₀	36 °/₀	40 °/₀

And the difference would be still greater if a Prussian boat were substituted for the toue.

This difference is evidently due to the respective forms of the boats, which, however, differ only in their extremities.

All three are flat at the bottom and of a rectangular form on the greatest part of their length.

The péniche is scarcely rounded at its two ends and the bottom is only raised in some parts a few centimeters; also, the coefficient of displacement amounts to 0.99 (1).

The toue is square at the stern, but somewhat pointed towards the bows, the bottom is often elevated a quarter of an ellipse on a length of 2 to 3 meters. The coefficient of displacement consequently descends to 0.97.

The Prussian boat is rounded at both ends in the form of a semicircle and is elevated to a quarter circle, by which the coefficient of displacement sinks to 0.935.

The volume of the rectangular parallelopiped formed by the immerged part measures 38.50 × 5 × 1.80 = 346.50; the total displacement and the possible guage of the three types is in round figures (2).

	Total displacement.	Effective guage.
Flemish péniche . . .	342 cub.m.	292 t.
Toue of the Saône . .	336	286
Prussian boat	328	278

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(1) The coefficient of the displacement of a boat in the proportion of its real displacement to the rectangular parallelopiped formed by its immerged part.

(2) The dead weight of the three boats being uniformly estimated at 50 tons.

It appears from the foregoing that by sacrificing 6 tons on the possible guage for the toue, and of 14 tons for the Prussian boat, mariners might obtain a considerable reduction in the resistance of their boats to traction and consequently realise a perceptible increase of speed.

The improvement of navigation plant in the sense of the preceding observations would, thus, exercise a favourable influence on the rapidity of transport.

II. NECESSARY EXCESS OF THE DEPTH OF A CANAL ON THE DRAFT OF THE BOATS.

It is generally admitted in France that the depth of a canal should exceed the draft of the boats by at least 0.20 m., and the excess is brought to 0.40 m. on canals of the greatest traffic.

It seems to us that it will be useful to examine if it is advisible to proceed further in this direction and to increase the depth at the same time as the width, when it is proposed to augment the wet surface of a canal.

On this point a very interesting experiment was made by Bossut in the last century by the aid of a wooden prism with a square base, sides of 0.65 m. and a length of 1.97 m., immerged to the half of its height. (1)

This prism was tugged with a uniform speed of 0.84 m. per second in a large basin, the dimensions of which might be considered as indefinite and gave under these conditions a resistance of 7.83 k.

Bossut then formed in the basin by the aid of wooden partitions a canal, of which he successively altered the depth and the width; the prism was then drawn at the same speed of 0,84 m. and the resistance to traction was measured in each case.

The results obtained are given in the following table, where the resistance observed in an indefinite space is taken as unit.

Free width on each side of the floating object.	Free height under the floating object.	Relative resistances.
Indefinite.	Indefinite.	1
Indefinite.	0.413 m.	1.10
Indefinite.	0.095 „	1.15
0.619	0.090 „	1.52
0.216	0.085 „	2.26
0.061	0.085 „	3.15

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(1) Bossut, Hydrodynamics.

The examination of this table apparently proves, that above a certain limit, the free height under the floating object has only a limited influence on the resistance to traction and that this influence depends more on the free width on each side of the floating object.

The first part of this observation is confirmed by experiments made by the engineer Barbet on 4 locks of the Scarpe and on the Sensée canal, the width of which is uniformly 5.20 m. (1).

Mr. Barbet measured the time which péniches of 5 meters in width and a depth of 1.80 m. took to enter from downstream in the chamber of the locks, under the action of a constant power, and found that the time varied as follows with the height of the water on the mitre sill.

Locks.	Height of water on the mitre sill H.	Duration of entering of the boat T.	*Remarks.*
Augustin's lock. . .	2.034	9' 36"	These figures are the averages of many experiments.
Gœulzin lock . . .	2.102	5' 55"	
Estrées lock	2.250	4' 20"	
Fressies lock. . . .	2.602	3' 36"	

It follows from this table that the time *T* is reduced:

a) from 9'36" to 5'55" when the height H increases from 2.034 m. to 2.102 m.
b) „ 5'55" „ 4'20" „ „ „ „ „ „ 2.102 m. to 2.250 m.
c) „ 4'20" „ 3'36" „ „ „ „ „ „ 2.250 m. to 2.602 m.

Mr. Barbet concludes from this „that the importance of bringing the height of water on the lower mitre sill of locks to 2.25 m. or 2.30 m. is very considerable but that a further increase scarcely appears justified by the results which would be obtained."

This conclusion possesses evidently very serious interest; and a study of the respective influences of the width and the depth of a canal on the resistances of boats to traction would probably lead to other conclusions not less important.

This study is related to the researches undertaken by Mr. de Mas and forms in our opinion the natural completion to them.

III. MINIMUM RADIUS TO BE ADOPTED FOR CURVES OF CANALS.

The width of a canal at the bottom should be increased in curves, the radius of which is below a certain limit, in order to allow of the crossing of two loaded boats.

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(1) Annales des Ponts et Chaussées 1885, 2e Semestre, pages 727 and following.

A ministerial circular of June the 19th 1880 has indicated as rule to be adopted the following arbitrary formula:

$$x = 10 \textit{ Meters} + \frac{380}{R}$$

in which x represents the width to be given to the bottom and R the radius of the axis.

This formula ceases to te applicable when R descends below 100 meters.

The same circular adds, also, that „as the width required increases rapidly above a radius of 200 meters, it is advisable not to go below this limit, at least unless local conditions render it necessary."

The St. Quentin canal has numerous curves of 100 and 200 meters of radius, and even several of 80 and 100 meters are met with.

The widening of these curves has been effected in such a way as to increase the minimum width of the bed of the canal to double the height of the arch, which has for its span the maximum length of the boats.

This widening has been calculated by the aid of the following formula:

$$x = \sqrt{L^2 + (l + 2\,R)^2} - 2\,R$$

in which L is the maximum length of the boats and l the normal width of the bed.

The length L has been taken at 40 meters and the width l at 12 meters, which gives the equation

$$x = \sqrt{1600 + (12 + 2\,R)^2} - 2\,R$$

from which two other approximative formulae have been deduced, one $x = 12\text{ m.} + \frac{800}{12 + 2\,R}$ applicable when $R = 150$ meters and the other $x = 12\text{ m.} + \frac{400}{R}$ applicable when $R = 300$ m. and more.

The values of x in these formulae have finally been increased by

0.60 m. for radii of 300 to 200 meters
0.90 m. „ „ „ 200 „ 150 „
and 1.20 m. „ „ under 150 meters,

so as to take into account the difficulty experienced by boats in manoeuvering in curves of small radius.

The widened curves have been successively connected with contiguous straight parts with a normal width of 40, 60 or 80 meters accordingly as the widening has been effected symmetrically on both sides of the axis, or only on the concave or only on the convex bank.

These arrangements have in practice given very satisfactory results in every respect; loaded péniches cross without difficulty even in curves of small radius and they navigate the curves when no other boat is present, without slackening speed.

Inspector General Flamant has, however, shown in a report inserted in the „Annales des Ponts et Chaussées (1881 1er Semestre)", that the power required to move a boat with a given speed in a curve of 100 meters of radius exceeds the double of that, which would produce the same speed in a straight canal; but his calculations did not take into account the widening of the bed, which amounts to 5 meters on all the extent of the curves in question.

By means of this widening we estimate that a radius of 100 meters may when necessary be adopted without serious inconvenience on a canal destined to be used by boats of 38 to 39 meters in length and 5 m. in width.

IV. PROTECTION OF THE BANKS OF CANALS.

The chief Engineer Peslin presented to the Vth Congress a detailed report on the consolidation of the banks of canals in the northern part of France.

We will confine ourselves to adding to this report a few observations relative to works of protection executed on the canals of the line from Belgium to Paris.

The different systems in use on these canals include the erection of masonry or stone walls with their foundation 0.40 m. below the water-line and extending to 0.30 m. on 0.40 m. above this level.

The base, which is of beton or dried stone is protected by a line of oak piles 0.10 m. or 0.12 m. in diameter and 1.50 m. to 1.70 m. in length, against the heads of which are nailed on the side of the bank cross planks also of oak and 0.25 m. to 0.30 m. in width and 0.03 m. to 0.04 m. in thickness.

The arrangements in elevation are divided in four different types:

1°. Stone walls at an incline of 45° formed of stone blocks averaging 0.25 m. in length, laid dry on a bed 0.15 m. in thickness, composed of broken stones of 0.08 m.;

2°. Dressing of thin beton 0.50 m. in depth at a slope of 45° and formed of two beds each of 0.25 m.; the inner bed being of steel dross moistened and strongly pressed, the outer bed in thin beton of steel dross in the proportion of 150 kilogrammes of hydraulic line to a cubic meter of dross;

3°. Dressing with masonry of bricks of a thickness of 0.22 m. on a slope of $^1/_2$;

4°. Masonry of bricks of a thickness of 0.34 m. with a front slope of $^1/_{10}$.

These four types offer sufficient resistance to the action of the waves and to the friction of empty boats.

The price per meter length varies according to the distance the materials have to be transported, for instance:

for type I, used on the lateral canal of the Oise and the southern part of the St. Quentin canal from 7 to 8 francs;

for type II, employed on the Escaut and the Northern part of the St. Quentin canal 3.50 to 4 francs;

for type III, used in the upper reaches of the two branches of this canal 5 to 6 francs;

for type IV, employed in the dividing reach of this canal 8 to 9 francs.

Compiègne, June the 29th 1894.

Translated by G. I. Rowland.

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VIth INTERNATONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

FIRST QUESTION.

Construction of navigation Canals affording operation at high speed.

REPORT

BY

H. WORTMAN,
Second-Class Engineer of the Waterstaat, Assen.

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THE PROTECTION OF CANAL BANKS IN THE NETHERLANDS.

REPORT

BY

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At the meetings of the first section of the fifth Inland Navigation Congress the question of the slope to be given on protected canal banks was the object of attentive examination, the result of which was, that the Congress expressed a wish that experiments should be made to determine the influence of the slope of the banks on the effect of the wash caused by the movement of steamboats, and that at the next Congress, with the help of the results of these experiments, the study of the best arrangements and the most economical construction for the protection of the banks of canals should be continued.

If it be desired that experiments should be made with regard to the influence of the slope on the effect of the wash, the results of which should be that the proportion between the height of the wash, the slope of the banks, the speed of the steamboats, the wet section of the canal, and the submerged main section of the vessel, could be expressed in figures, it would be necessary to construct for the purpose a section of a canal with banks of different slopes, or to prepare a model of such a canal on a small scale.

This has not yet been done and exact figures concerning the proportions in question will thus not be found in this report.

In practice the figures would have however only a relative value, as it is difficult to bring into calculation different elements depending on local circumstances, such as the material of which the dressing of the canal is made and the variation of the water level.

Still, perhaps a little more light may be thrown upon the question if the works protecting the banks be examined in connection with the dimensions of the canal and the steamboats which navigate it.

The protection of canal banks which has only appeared generally necessary since the increase of steam navigation on canals, which so works upon the banks, remains still in a stage of development and the various systems which have been adopted may be regarded as so many experiments.

It is therefore well that the examples presented be collected and compared, in order that the good examples may be followed up, as well as that the bad may serve as warnings. Various systems which have been tried on Dutch canals will be explained in this report.

This will be particularly useful in the further study of the subject, as in the treatment of the question at the last Congress, where the advantages of steep inclines on canal banks were discussed, Dutch canals were several times taken as examples.

The details given in this report are for the most part borrowed from the reports demanded by the Administration of the Royal Institute of Engineers from the Engineers charged with the control of canals and are with the greatest willingness supplied by the latter.

As will be shown there are in the Netherlands many systems of protection which, however, may be collected into a few principal types.

Before describing the systems it will be well to give some general information concerning canals in the Netherlands.

General remarks concerning canals.

The canals in the Netherlands may be divided into two classes. Those of one class, which are found in the lower provinces, were originally land-drainage canals which have since been employed for navigation. They are properly speaking not *rivers* because they do not freely carry their waters from higher regions to the sea. They are rather the old *kreken* (creeks), which have been left in the un-diked land of the maritime provinces and which now by the aid of mills and steam engines carry off the water from the *polders*.

These canals, called *boezemkanalen*, some of which are expressly dug for drainage, are kept as much as possible at a certain level by means of locks, and sometimes by steam-engines, and are often managed by the *waterschappen* who are interested in the land-drainage. Of this class in North Holland are the *Amstel*, the *Zaan* and the *Spaarne*; in the province of South Holland the *Gouwe*, the *Rotte*, the *Schie* and the canal called the *Leidsche Rhine*; in the province of Utrecht the *Vecht*; in the province of Friesland the numerous canals which connect the lakes or pools still existing in this province and in the province of Groningen the *Damsterdiep* and the *Reitdiep.*

The dimensions of the canals are determined with a view to the interests of land-drainage.

As a rule they are of considerable width which, however, varies very much at different points, and are not of great depth. Thus the *Amstel* has a width of 50 m. to 90 m. and a depth of 2.35 m.; the *Spaarne* a width of 40 m. to 2.35 m. and a depth of 2.20 m. to 3.70 m.; the *Schie* a width of 24 m. to 42 m. and a depth of 2.50 m.

These canals which form the waterways between many of the most important towns have been for centuries taken into the service of navigation; and in this century a very active steam service has been developed on some of them; such as the Schie, the Zaan, the Amstel and the Gouwe. Meanwhile, the canal banks have relatively suffered less in consequence as the width of water is very great in proportion to the depth and to the dimensions of the artificial works through which vessels have to pass.

Quite another sort of canals are those which have been excavated for the benefit of navigation, to which dimensions have been given not greater than is required for the passage of the largest ships expected to use the canals.

Of this kind we have in the first place the canals for sea-going vessels such as the *North Holland Canal*, which was dug in 1824 to connect Amsterdam with the North Sea near the Helder, and further, the *North Sea Canal* from Amsterdam to Ymuiden, the *Canal through Voorne*, dug in 1831 to conduct ships from Rotterdam to the sea near Hellevoetsluis, the *Canal through Walcheren* and the *Canal through South Beveland*, which two canals unite the two branches of the Scheldt, and the *Terneuzen Canal* which connects Ghent with the Scheldt.

Of all these canals only the North Sea Canal and the Terneuzen Canal are regularly used by sea-going steamers. The North Holland Canal and the canal through Voorne are rarely visited by these vessels since Amsterdam and Rotterdam have been connected by better ways with the North Sea. The canals through Walcheren and through South Beveland were dug to replace the branches of the Scheldt which had been dammed for the construction of the railway, and are actively used by inland craft but seldom by sea-going vessels.

Finally, many canals have been excavated for inland navigation, among which the *Amterdam-Merwede Canal* just lately finished is the most important.

A number of these canals are in the eastern and southern provinces, where the country is more hilly and many locks are necessary to regulate the fall of the water.

It is on canals of the second sort, which are of limited dimensions and mostly excavated in sandy soil, that the question of bank protection has been most prominently brought forward. Most canals, and amongst them all those belonging to the State, are navigable for steamboats. The suction of the steamboats and the damaging influence of the wash caused by them has in the course of time shown itself everywhere.

On some canals, as on the *Dedemsvaart* in Overijssel and the *Hoogeveensche vaart* in Drenthe, navigation by steamboats is forbidden, and here the protection of the banks can be effected by very simple means.

Dimensions of canals and steamboats.

For all canals belonging to the State, as well as many others, rules have been fixed by which is determined the highest speed allowed to steamboats and the greatest dimensions of vessels to be admitted.

The speed of steamboats is usually regulated by their draught, for the deeper boats a lesser speed being allowed than for those of smaller draught.

The speed allowed is usually slightly exceeded by the vessels. The dimensions of the vessels are generally regulated according to the dimensions of the locks and bridges which they have to pass. The maximum measurement is, however, seldom reached by the vessels.

The ratio between the wet section of the canal and the submerged main section of the largest vessels regularly navigating the canal is therefore as a rule more favourable than it would be if the canal was used by vessels of the largest class admissible.

For the canals the bank protections of which are described in this report the ratio referred to is given in the following table as it would be if the canal and the vessels were of the regulation dimensions, and as it is now in reality.

Herein is also given the speed which is, according to the rules, allowed to steamboats of the largest size, admissible and the speed of the largest boats which at present regularly use the canal.

Canal.	According to the regulations.			Actual state of things.			Speed.	
	Wet Section of the canal. sq. m. (1)	Submerged main section of largest vessels sq. m. (2)	Ratio. s. l./s. m.	Wet Section of the canal. sq. m.	Submerged main section of bulk of largest vessels. sq. m.	Ratio. s. l./s. m.	Allowed for largest steamboats. km per hour.	Of the largest boats using the canal. km per hour.
Canal through Walcheren	288	133	1 : 2.16	288	14.82	1 : 19.4	7.5	15
Canal through South Beveland	166.40	92	1 : 1.8	168.30	10	1 : 16.8	7.5	9
Terneuzencanal	194	61.25	1 : 3.17	225	50	1 : 4.5	8.7	8.7
Dieze	113	21.30	1 : 5.3	113	9.40	1 : 12	10.8	10.8
Meppelerdiep near Meppel.	50	13.3	1 : 3.75	53	6.85	1 : 7.74	7.5	7.5
„ „ Zwartsluis.	61.50	13.3	1 : 4.62	65	6.85	1 : 9.5	7.5	7.5
Amsterdam-Merwede-Canal.								
part from Amsterdam to Utrecht.	88	26	1 : 3.38	88	19.28	1 : 4.56	7.5	6.5
„ „ Utrecht to Vreeswijk.	84.50	26	1 : 3.25	84	19.28	1 : 4.36	7.5	6.5
„ „ Vianen to Gorinchem.	86	26	1 : 3.31	86	19.28	1 : 4.45	7.5	6.5
South Willemsvaart.								
between the Dieze and N°. I lock.	31.40	11.91	1 : 2.64	40	9.8	1 : 4.08	7.2(3)	7.2
between N°. 1 lock and N°. 2 lock.	32.66	11.91	1 : 2.75	33	9.8	1 : 3.37	7.2	7.2
in the province of Limburg	29.82	11.91	1 : 2.5	31	9.8	1 : 3.16	7.2	7.2
near Maastricht	39.8	11.91	1 : 3.34	39.80	10.45	1 : 3.8	7.2	4.5
South Willemsvaart after the clearing now being executed	45.31	11.91	1 : 3.8	45.31	9.8	1 : 4.62	7.2	7.2
Canal from Maastricht to Liège.	29.82	11.91	1 : 2.5	30	10.45	1 : 2.87	6	4.5
Weesper Trekvaart	43	15	1 : 2.86	44	10.27	1 : 4.28	7.8	7.8
North Holland Canal.	130.90	68	1 : 1.93	150	4.85	1 : 30	7.5	14.5
Rhine-Schie Canal (4)								
part from the Schie to the Hague.	61	16	1 : 3.82	—	—	—	9	—
„ „ „ Hague to Leiden	46.28	10.22	1 : 4.52	—	—	—	9	—
Willemsvaart (Overijssel)	73.24	33.6	1 : 2.18	63	9.35	1 : 6.73	6	6
Canal from Groningen to Lemmer.								
part from Groningen to Stroobos.	—	—	(5)	28	7.6	1 : 3.68	—	7.8
„ „ Stroobos to Gerbenallesverlaat and the Kolonelsdiep.	36	7.6	1 : 4.7	34.50	7.6	1 : 4.54	10	10

Canal.	According to the regulations.			Actual state of things.			Speed.	
	Wet Section of the canal. sq. m.	Submerged main section of largest vessels. sq. m.	Ratio. $\frac{s.\ l.}{s.\ m.}$	Wet Section of the canal. sq. m.	Submerged main section of largest vessels. sq. m.	Ratio. $\frac{s.\ l.}{s.\ m.}$	Allowed for largest steamboats. km. per hour.	Of the largest boats using the canal. km. per hour.
Canal from Groningen to Ulrum.	—	—	(5)	14	3.42	1 : 4.1	7.8	7.8
Damsterdiep	—	—	(5)	56	4.2	1 : 13.3	—	7.2
Canal from Leeuwarden to Harlingen	36	7.6	1 : 4.7	—	—	—	10	(4)
Drentsche Hoofdvaart.								
upper part	27.50	6.40	1 : 4.3	27	3.60	1 : 7.5	6	6
other parts	24.40	6.40	1 : 3.81	24	3.60	1 : 6.67	7.5	7.5

(1) The wet section of the canal given in the first column is taken from the «Overzicht der Scheepvaartkanalen» published by the «Ministerie van Waterstaat, Handel en Nijverheid."

(2) The submerged main section of vessels in the second column is calculated from the dimensions of the largest vessels as fixed in the regulations whereby for vessels the ratio between the width and the depth is reduced to 19 : 20.

(3) For steamboats which do not appear to cause any injurious effects on the banks, a speed of 10.8 km. per hour may be allowed.

(4) The canal is not yet entirely opened for steam traffic.

(5) The largest dimensions for vessels are not given in the regulations. It is only stated that steamboats with a draught of more than 1.25 m. may not travel at a greater speed than 7.5 km. per hour.

From the above it appears that if the Dutch canals were regularly used by steamboats of the largest dimensions allowed, the ratio between the submerged main section and the wet section of the canal would not generally be favourable.

The ratio is only for a few of the canals given as greater than 1 : 4, and of these again some, such as the Dieze and the Meppelerdiep, are not canals excavated for navigation but canalised rivers.

On the sea-water canals the regulation ratio is least. On the most important inland navigation canals, such as the Amsterdam-Merwede Canal and the South Willemsvaart it is about 1 : 3.

It appears also that the Dutch canals are generally used by steamboats of considerably smaller dimensions than the maximum allowed. The proportion above referred to is thus in reality much more favourable, and for three canals, the South Willemsvaart, the canal from Maastricht to Liége, and the canal from Groningen to Stroobos, it is to less than 1 : 4.

The proportion is particularly favourable for canals which have been constructed for sea-going vessels, such as the canals through Walcheren and through South Beveland and the North Holland canal which are now regularly navigated by inland boats only.

It is very rarely that large sea-going steamers visit these canals and even then they are tugged at a low rate of speed.

The canal through Voorne also, of which no mention is made in the table because the bank protection only consists of withies, which answers the purpose very well, is in the same condition.

The ratio $\frac{s.\ i.}{s.\ m.}$ for the canal according to the regulation amounts to $\frac{78\ sq.\ m.}{140\ sq.\ m.} = 1.8$, and is actually $\frac{10\ sq.\ m.}{160\ sq.\ m.} = 1 : 16$.

The North Sea Canal, throughout the greater part of which there is on both sides of the navigable channel a submerged berm 30 m. in width, has not shown any need for the protection of its banks. The Terneuzen Canal is the only one of the canals treated in this report that is regularly used by sea-going steamers with their own power.

The ratio for this canal is 1 : 4.5.

The speed of steamboats on the canals in the Netherlands appears to be very considerable and may be taken at an average of 7 km. per hour. The maximum speed admitted in the regulations are mostly exceeded, as it is very difficult to prove these irregularities.

The steamboats of which the dimensions are here given are all screw-boats.

The canal through Walcheren and the Willemsvaart in Overyssel alone are navigated by paddle-boats, which, however, are of less dimensions than the largest screw-boats using the canal.

System adopted for the protection of canal banks.

The principal systems adopted on the Dutch canals for protection of banks are shown at the end of this report on Plates 1—10.

For each canal is given the section of the canal and of the largest steamboat regularly using the canal, as they are actually met with.

Among the systems of bank protection are not included the various works consisting of fascines and grass-slopes which are still met with on the sides of a number of canals.

The fascine work, which if it is not always under water, must be continually renewed, thus causing considerable expense for maintenance, has been found to be everywhere quite insufficient on canals where steam navigation is important and it is being gradually replaced by more solid constructions.

Where a bank protection must be chosen with the object of rendering canals suitable for steamboat traffic at high speed, fascine work must thus be abandoned, so that it does not come within the scope of this report.

A description of the systems adopted follows below, with which is also given the expense of construction.

The systems which show remarkable differences in detail may be grouped in a few principal classes:

The principal classes are:

1st. strengthening of the original slopes.

2nd. the forming of new and fairly steep walls.

3rd. a combination of both classes.

To the first class belongs a talus of stone and gravel, to the second the embankment formed either by a row of stakes side by side, or by a row of planks forming a wall, while to the third class belongs the embankment above which the slope is protected by a stone or gravel revetment or a moderately steep wall.

I.(*a*) STRENGTHENED TALUS.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
Pl. I, Fig. 1.	**Canal through South Beveland** connecting the two branches of the Scheldt from Hansweert to Wemeldinge.	Sand and peat covered with a layer of clay 0.50 m. thick.	Talus of Vilvorde and Lessines stone, supported by a row of creosoted pine piles 0.80 m. long, of which 5 go to a metre. The piles are supported by a bed of stones. The stone talus rests on a layer of clay, covered by a layer of withies and gravel. Height protected 1.65 m. Protected surface per metre in length, 6 square metres.	fl. 19	The protection has been effected since 1883 and keeps in fairly good condition. The bed of stones at the foot is very satisfactory.
Pl. I, Fig. 2.	**Canal through Walcheren** connecting the two arms of the Scheldt from Flushing via Middelburg to Veere.	Sand mixed with clay.	Talus of Vilvorde and Tournay stone on a layer of gravel. On the slope a layer of clay which is continued to the bed of the canal. Height protected 1.95 m. Protected surface per metre in length 6 square metres.	fl. 14.50 (without the clay dressing).	The protection was effected in 1870. For want of a row of piles for support of the foot of the talus, the lower part sank, afterwards the slope was washed away. Piles have been placed along a certain distance.
Pl. I, Fig. 3.	**Terneuzen Canal,** the Dutch part of the canal from Ghent to the Scheldt at Terneuzen.	Fine sand covered with a thin layer of clay.	Talus of Vilvorde stone on a layer of gravel between rows of piles The talus is supported at foot by a row of pine piles 1.20 m. long, of which 5 go to the metre in length. Above the stone talus a layer of withies. Height protected 2.20 m. Protected surface per metre 5 square metres.	fl. 13	The protection was effected in 1880. Through the washing away of the soil under the stone talus the latter has sunk in many places as shown in the drawing.
Pl. 2, Fig. 4.	**Dieze** from Bois-le-Duc to the Maas near Crèvecœur.	Sand mixed with clay.	Stone slope of Belgian stone between supporting piles with rush beds.	fl. 13.33	The protection was effected in 1880—1889. The row of piles at

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
			The talus is supported at the foot by a row of pine piles 1.60 m. long, of which 5 go to the metre. Protected height 3.40 m. Protected surface per metre in length 10.75 square metres		the foot of the stone talus, which had sunk on account of the washing away of the slope, is replaced at many points by a row of piles 2.50 m. in length. Through the inundations of the Maas the water of the canal may rise very high; therefore the protection of the slope is carried to this height.
Pl. 2, Fig. 5.	**South Willemsvaart** from Maastricht to Bois le-Duc, part between lock No. 5 and No. 9.	Fine sand.	Talus of granite pebbles between three rows of supporting piles covered with withies. The foot of the talus is supported by a row of pine piles 1.80 m. in length, of which 5 go to the metre. Protected height 1 m. Protected surface per metre in length 2.85 square metres.	fl. 3.50	The protection was effected in 1885 and is now nearly useless. The piles stand at too great a distance from one another whereby the sand behind them is washed away and the talus has sunk. The piles are also too short and lean over by reason of the weight of the stone.
Pl. 2, Fig. 6.	**Meppelerdiep** from Meppel to Zwartsluis, part near Meppel.	Sand.	Talus of broken stone on a layer of clay. The foot of the slope is supported by a row of pine piles 1.60 m. long, of which 2 go to a metre, and a joist which is fixed to the piles. Protected height 1.40 m. Protected surface per metre in length 3.77 square metres.	fl. 5.70	The protection was effected in 1892 and keeps in good condition. On account of the great width of the canal there is little danger of the slope under the foot of the talus being washed away.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*

I*b*. STRENGTHENED TALUS WITH FIRM FOUNDATION.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
Pl. 3, Fig. 7.	**Amsterdam-Merwede-Canal,** from Amsterdam via Utrecht to the Merwede near Gorinchem, part between Amsterdam and Nigtevecht.	Very soft peaty ground (which was dumped at the digging of the canal).	Gravel between 11 supporting piles supported at the foot by a compact row of pine piles 1.60 m. in length. Protected height 1.75 m. Protected surface per metre in length 3.90 square metres.	fl. 6.50	The protection was effected in 1890 and continues in good condition. The layer of gravel has to be filled in from time to time. In many places the soft ground of the canal-dikes has sunk away, whereby the talus has followed the new slope without being destroyed, as is shown in the drawing. For the purpose of strengthening the upper rows green willow has been employed which now has sprouted.
Pl. 3, Fig. 8.	**Amsterdam-Merwede-Canal** Part between Utrecht and Vreeswijk.	Sand covered with a layer of clay.	Gravel between 4 supporting piles supported at the foot by a compact row of piles 1.60 m. in length. Above the gravel a talus of brick. On the bank a layer of clay. Protected height 1.50 m. Protected surface per metre in length 3.35 square metres.	fl. 5.70	The protection was effected in 1887 and keeps so far in good condition. The layer of gravel has to be filled in from time to time.
Pl. 3, Fig. 9.	**South Willemsvaart** part between Maastricht and the Belgian frontier. (Along the canal from Maastricht to Liège a similar system of protection is adopted).	Grit mixed with clay.	Talus of stone on a layer of grit supported at the foot by a row of pine piles 2 m. in length, at distances of 1.50 m. from each other, above which a tie and a row of horizontal planks. Protected height 0.80 m.	fl. 7.70	The protection was effected in 1882 and keeps in good condition, though in some places the grit is washed away between the piles and the spaces have to be filled in. Hori

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
			Protected surface per metre in length 1.44 m.		zontal planks are used because the bed was too hard for the placing of large planks. Where the bed allows of it vertical planks 0.75 m. length have been used.
Pl. 4, Fig. 10.	**South Willemsvaart** in the province of Brabant between locks Nos 4 and 5.	Sand.	Stone talus of granite pebbles on a layer of gravel and a layer of clay forming a berm 1 m. wide which is submerged at the usual water-level. The talus is supported at the foot by a compact row of pine piles 2 m. long, the seams of which are covered by stakes 1.20 m. in length. Protected height 0.50 m. Protected surface per metre in length 2 square metres.	fl. 4.83	The protection was effected in 1888, and keeps in good condition. Only the stone has had to be removed severa times, and the layer filled up, which shows that some sand is lost between or under the piles. In more recent works of this type piles of a length of 2.50 m. have been used.
Pl. 4, Fig. 11.	**South Willemsvaart** in the province of Brabant between lock No 9 and the frontier of the province of Limburg.	Sand.	Layer of gravel on a flat layer of broken stones forming a berm 1 m. wide, which is submerged at the usual water-level. The talus is supported at the foot by a compact row of pine piles 2 m. in length, the seams of which are covered with stakes, 1.20 m. in length. At the end of the berm a row of stakes with fascine-work. In some places a layer of clay is placed under the layer of broken stone. Protected height 0 70 m. Protected surface per metre in length 2 square metres.	from fl. 2.60 to fl. 2.90	The protection was effected in 1889 and keeps in good condition. Only the berm has to be filled in now and then with rubbish. The piles are considered to be too short. In some places the berm 1 m. wide is covered with withies in place of rubbish. The latter, however, will not grow.

Number f the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
Pl. 4. Fig. 12.	**South Willemsvaart** in the province of Brabant, protection along the enlarged canal, sections between locks Nos. 1 and 6.	Sand.	Stone talus of granite pebbles on a layer of grit, and two flat layers of pieces of rubbish with a submerged berm as in figs. 11 and 12. The talus is supported at the foot by a compact row of pine piles 3 m. in length.	fl. 4.78	The protection was effected in 1892 and 1893 and keeps in good condition. The longer piles are used, as the piles of the other types proved to be too short.
Pl. 4. Fig. 13.	**Amsterdam-Merwede Canal** part between Utrecht and Vreeswijk.	Sand covered with a layer of clay.	Layer of rubbish between two rows of stakes forming a flat berm 0.50 m. wide. Above a stratum of bricks. The layer of rubbish is supported at the foot by a compact row of pine piles 1.60 m. in length. Protected height 1 m.	fl. 4.50	The protection was effected in the years 1885–1890. Through the washing away of the slope under the row of piles there is a danger of their leaning forward and falling into the canal. Where the washing away has been the greatest a second row of piles 2 m. in length has been placed in front of the first row.

II. REVETMENTS.

a. *Compact rows of piles.*

Pl. 4, Fig. 14.	**Sonth Willemsvaart** in the province of Limburg.	Sand alternated with peat.	Compact row of pine piles 1.80 m. in length behind which it is filled in with grit between two rows of bundles of withies. Later, for the support of these piles, a second row of piles was driven in, 4 m. in length, at distances of 1.50 m. and joined by a tie.	fl. 2.50 and with a second row of piles. fl. 6	The protection was effected in the years 1881—1889. Since it appeared that in front of the piles the bank washed away and the piles threatened to fall into the canal the second row of piles was driven in in 1891.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks*
			By this means the filling of grit is replaced by a filling of peat, covered by a thin layer of grit. In front of the piles a heap of grit.		
Pl. 5, Fig. 15.	**Binnen Aa** in the province of Groningen from Nieuweschans to the Dollard.	Clay.	Compact row of pine piles 2 25 m. to 3 m. long on a slope of 1 in 6 joined by a belt made of piles cut in two. Behind the piles a heap of turf, above which grass forming a flat berm of 0.50 m.	fl. 5	The protection w effected in 1884—18 without the tu When it appeared th the ground wash away between t seams of the piles t filling of turf w added. Steamboats do n visit this canal.
Pl. 5, Fig. 16.	**Canal from Groningen to Lemmer** part from Groningen to Stroobos called the **Hoendiep**. The same system is also adopted on the canal from Groningen to Ulrum near Zoutkamp.	Clay and sand mixed in some places with peat.	Compact row of pine piles 2.50 m. and 3 m. in length, with a slope of 1 in 4, joined by a belt. Behind the piles a layer of rubbish is placed, at least 0.25 m. thick, to the depth where the slope in front of the piles is washed away.	fl. 7.80	The protection has be effected since 1882 a keeps in good cond tion. If the ground front of the piles further washed aw the layer of rubbi sinks after it and h to be filled in ag from above. In a f places where the sl is washed away to great depth the pi lean over. Supporti piles are then pla at distances of 3 or anchors are used
Pl. 5. Fig. 17.	**Canal from Groningen to Lemmer** part from Stroobos to Gerben alles verlast in the province of Friesland.	Sand mixed with a little clay	Compact row of pine piles 3 m. in length, bound by a belt, and supported by other piles of 4 m., placed at distances of 2 m. All the wood is creosoted. Behind the piles a filling of rubbish.	fl. 14	The protection was fected in 1889 and ke in good condition. T supporting piles are jured from time to ti by vessels coming i collision with them.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks*
Pl. 5, Fig. 18.	**Weesper Trekvaart** is between the Amstel near Amsterdam and Diemerbrug being a part of the old navigable way from Amsterdam to the Rhine.	Peat mixed with clay, and withies, wood and rubbish belonging to old protection works.	Compact row of pine piles 1.60 m. in length behind which a filling of rubbish covered with stone.	fl. 2.90	The protection was effected in 1876 and does not keep in good condition; through the washing away of the ground in front of the piles they lean forward in various places.
b. *Revetments of planking.*					
Pl. 6, Fig. 19.	**South Willemsvaart** part between the Dieze et Bois-le-duc and lock N° 1.	Fine Sand.	Pine piles 4.50 m. in length at distances of 1.50 m.; on the piles a tie, behind which a row of planks dove-tailed into one another; length of the planks 3 m. The piles and planks are placed at a slope of 1 in 10.	fl. 23	The protection was effected in 1860—1864 and has kept in good condition. In some places the piles have lost their support by the washing away of the ground and the revetment has sunk forward.
Pl. 6, Fig. 20.	**Canal from Dokkum to Gerbenallesverlaat** in the province of Friesland.	Sand with a little clay.	Row of planks 1.60 m. long placed next to one another joined by a belt which is supported by slanting piles 2.50 m. in length placed at distances of 2 m. Wood all creosoted pine.	fl. 7	The protection was effected in 1889 and keeps in good condition. Before 1889 the wood was not creosoted, and the cost was fl. 4 per metre.
Pl. 6, Fig. 21.	**Willemsvaart** in Overyssel, from Zwolle to the Yssel near Katerveer.	Sand, on which a layer of peat 0.25 m. to 1 m. thick, and a layer of clay of 0.50 m.	Oaken piles 2.50 m. to 3 m. long at distances of 1.20 m., with a slope of 1 in 10. Behind the piles an oaken plank, against which a row of pine-wood planks 2 m. in length placed next to each other without fastening.	fl. 12.30,	The protection was effected in the years 1874—1877 and has not kept in good condition. The piles and planks proved too short, and the ground washed away through the seams between planks. In some places an endeavour has been made to prevent this by placing behind the planks wooden partitions 1.20 m. in height.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
Pl. 6, Fig. 22.	**Willemsvaart.**	The same as for fig. 21.	Pine piles 4.50 m. in length at distances of 1.20 m. at a slope of 1 in 10. Behind the piles a belt of pinewood, against which a row of planks fitting into one another. These are 3 m. in length. Above the piles and against the front of them planks are fixed as a protection against collisions.	fl. 17.75 Without the planks against the piles the cost is fl. 13.25	The protection was effected in the years 1890—1893 and keeps in good condition. The slope above the revetment formed of grass-beds at an incline of 1½ in 1 cannot withstand the wash and is in some places provided with a talus of brick.
Pl. 6, Fig. 23.	**Meppelerdiep** from Meppel to Zwartsluis.	Sand covered with a layer of peat 1.50 m. thick.	Pine piles 2.60 m. or 3 m. in length at distances of 1 m., at an incline of ½ in 1. Behind the piles wooden partitions made of horizontal and perpendicular planks crossed over each other, with the under part reaching to 1.20 m. or 1.40 m. below the water-level. On the front of the piles a belt is applied. All is of pine-wood, and with the exception of the lower half of the partition all creosoted. Behind the revetment a berm of rushes 0.50 m. wide.	fl. 9.50	The protection was effected 1886 and keeps in good condition. Only at high-water level which frequently is reached the slope above the revetment is now and then damaged.
Pl. 7, Fig. 24.	**North Holland canal** from Amsterdam to Helder part from Zijpe to Nieuwediep.	Sand in a few places containing a little clay.	Square pine piles, called *kolters*, 3.75 m. in length at distances of 0.75 m. at an incline of 1 in 20. Behind the piles a belt against which a row of planks 2.25 m. long. The seams between the planks are stopped with	fl. 7	The protection was effected 1887 and keeps in good condition. Before that year the same construction was adopted, but the piles were placed at distances of 1 m., and the planks were 2 m. in

Number of the Plate	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
			planks (*teugels*). Behind the revetment a berm covered in some parts with rushes.		length. These revetments made in 1870—1875 now lean forward in many places through the pressure of the ground as the slope is washed away.
Pl. 7. fig. 25.	**North Holland Canal**, part between the Willemsluizen near Amsterdam and Schouw.	Peat, covered with a layer of clay 1 m. thick.	Square pine piles (called *juffers*), 5 m. long at distances of 0.80 m. at an incline of 1 in 20. Behind the piles a plank against which a row of heavy planks 3.50 m. or 4.50 m. long, the seams covered with *teugels*. In front of the piles a belt. The revetment is anchored at distances of 2.40 m. with iron anchors (*trekankers*) fastened to piles 3 m. long. Behind the revetment a berm of rushes has been formed.	fl. 15.80	The protection was effected in 1861 and renewed in 1888. This type shows that as soon as the deepening of the slope in front of the revetment increases longer anchors and longer piles are necessary.

III. MIXED TYPES.

a. *Revetments with strengthened slopes.*

Pl. 7, fig. 26.	**North Holland Canal**, part between the Willemsluizen near Amsterdam and Schouw.	Peat, covered with a layer of clay 1 m. thick.	Square pine piles (*kolters*) 3.75 m. long at distances of 0.75 m. at an incline of 1 in 20. Behind the piles a plank, against which a row of heavy planks 2.50 m. long the seams covered by *teugels*. The revetment is strengthened at distances of 2.25 m. with iron anchors 2.25 m. long to an anchor pile of oak.	fl. 10.50	The protection was effected in 1880 and has not kept in good condition. The woodwork which has been brought to more than 0.15 m. above the water-level is liable to decay and will soon have to be renewed. The stone talus sinks in the very soft ground,

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
			Behind the revetment a filling of rubbish with a covering of granite stones.		and it is now being gradually done away with and replaced by a berm of rushes.
Pl. 7, fig. 27.	**North Holland Canal**, part between Schouw and Westgraftdijk.	Sand, on which a layer of peat and clay 4 m. thick.	Square pine piles (*kolters*) 3.75 m. long at distances of 0.70 m. at an incline of 1 in 20. Behind the piles a plank against which a row of heavy planks 2.50 m. long, the seams covered with *teugels*. Behind the revetment a layer of rubbish on which a talus of granite stones forming a berm 1.50 m. wide.	fl. 11.33	The protection was effected in 1879 and has kept in fairly good condition.
Pl. 8, fig. 28.	**Terneuzen Canal**.	Fine sand covered with a thin layer of clay.	Row of pine planks fitting into each other 2.75 m. long bound by an oak belt. At distances of 3 m. the revetment is anchored by iron anchors alternately 2.80 m. and 3.20 m. long to an anchor pile 2.50 m. long with cross pieces of pine wood. Behind the revetment a layer of rubbish is laid 1 m. wide.	fl. 14.20	The protection was effected in 1892. Where the depth in front of the row of planks is more than 1.50 m. stones are thrown in. This expense is not included in the figures given.
Pl. 8 fig. 29.	**Rhine-Schie canal**, from the Schie at Delft to The Hague, and to the canal called „de Oude Rijn" to Leiden.	Clay mixed alternately with peat and sand.	Square pine piles (*kolters*) 3.50 m. or 5 m. long at distances of 1 m. at an incline of 1 in 10. Behind the piles a belt, against which a row of planks fitting into each other 2 m. or 4 m. in length.	fl. 13 and fl. 14	The protection was effected in 1890 and 1891. Where there is a berm to the revetment the piles and planks are short (3.50 m. and 2 m.) and where this is not the

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks*
			At distances of 3 m. the piles are secured by iron anchors 2 m. or 3 m. long fastened to a pine pile with cross-pieces. Above the revetment a stone talus made of basalt on a layer of broken stone, under which is placed a layer of clay.		case longer (5 m. and 4 m.). The part between Delft and The Hague was opened to navigation for steamboats March 1st 1894. The canal to Leiden is not yet open to steamboats.
Pl. 8, Fig. 30.	**Amsterdam-Merwede canal**, part from Utrecht to Vreeswyk	Sand covered with a layer of clay.	Pine piles (*kolters*) 3.75 m. long at distances of 0.70 m. at an incline of 1 in 10. Behind the piles a plank against which a row of heavy planks 2.75 m. long. The seams covered with *teugels.* Behind the revetment a talus of broken stone.	fl. 11.	The protection was effected in the years 1885—1890 and keeps in good condition.
Pl. 8, Fig. 31.	**Amsterdam-Merwede canal**, part from Vianen to Schotdeuren near Gorcum.	Clay and peat.	Pine piles 1.60 m. long at distances of 1 m.; on the piles a tie behind which a row of planks 1.50 m. long and fitting into each other. Above the revetment a talus of bricks on two even layers of broken stone.	fl. 10.	The protection has been laid since 1882 and keeps in good condition. Formerly a type was adopted of which a drawing is given at the side of fig. 31. The foot of the talus was here formed by a row of pine piles 2 m. long, at distances of 1 m. behind which a plank 0.28 m. high. The cost of this type is fl. 4. The protection appeared entirely insufficient as the ground washed away under the planking. Then in some places heavy perpendicular planks were placed behind the planking.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
b. *Revetments with steeper walls.*					
Pl. 9, Fig. 32.	**Damsterdiep** Canal from Groningen to Delfzijl.	Light clay.	Row of planks 2 m. long fitting into each other at an incline of ½ in 1 fastened against a belt of oak. On this a brick wall built without mortar and covered on the top with masonry at an incline of ½ in 1.	fl. 7.40	The protection was effected in 1878 and keeps in very good condition.
Pl 9, Fig. 33.	**Damsterdiep.**	ditto.	Pine piles 3 m. long, at distances of 2 m. at an incline of ½ on 1. Behind the piles a belt of oak against which a row of planks 2 m. long fitting into each other. On the revetment a wall as in fig. 32.	fl. 8	The protection was effected in 1882 and keeps in very good condition.
Pl. 9, Fig. 34.	**Damsterdiep.**	ditto	Compect row of pine piles 2 m. long at an incline of 1½ on 1. Behind the piles a belt and a row of planks 0.50 m. long. On the revetment a wall as in fig. 32.	fl. 8.30	The protection was effected in 1877 and keeps in very good condition. In some places the row of heavy planks was only applied after it appeared that the ground washed away between the seams of the piles.
Pl. 9, Fig. 35.	**Binnen Aa.** (Province of Groningen) near the lock named Nieuwe Statenzijl.	Clay.	Pine piles 5.25 m. long at distances of 2 m. at an incline of ½ on 1. On the piles a belt of pine wood in front of which a row of planks 2.50 m. long. On the revetment is piled a wall of bricks without mortar, with a layer of masonry at the top with a slope of ½ on 1.	fl. 31.66	The protection was effected in 1884 and keeps in good condition. On the Binnen Aa there is no steam navigation. It was necessary here to give a great height to the wall on account of the great variations in the water-levels.

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
Pl. 9, Fig. 36.	**Canal from Groningen to Lemmer.** Part in the province of Friesland called **Kolonelsdiep.**	Sand.	Oaken piles 3 m. long at distances of 1 m. at an incline of ½ in 1. Behind the piles a belt of oak against which a row of planks 2 m. long. On the revetment is piled a brick wall without mortar, with a slope of ½ in 1 covered with a layer of masonry. Behind the wall a layer of turf.	fl. 9.10	The protection was effected in 1884 and keeps in good condition.
Pl. 10, Fig. 37.	**Canal from Leeuwarden to Harlingen.**	Sand containing clay.	A compact row of pine piles 2 m. long fastened against a belt of oak. The caps of the piles are sawn off obliquely and upon them is built a brick wall without mortar with a slope of $^3/_4$ in 1 and covered with a layer of masonry.	fl. 8	The protection was effected in 1893. The canal is not yet completed in its entire length.
Pl. 10, Fig. 38.	**Drentsche Hoofdvaart**, canal from Meppel to Assen, part near Havelte.	Sand.	Open piles 1.60 m. long at distances of 1 m. with a slope of ½ in 1 upon which a tie with the upper side 0.40 m. below the level of the canal. Behind the piles a belt against which a row of planks 1 m. long, the seams covered with *teugels*, all of pine wood. On the tie a brick wall without lime at an incline of $^3/_4$ in 1.	fl. 6.50	The protection was effected in 1892 and keeps in good condition.
Pl. 10, Fig. 39.	**Drentsche Hoofdvaart**, part between Assen and Smilde.	Sand covered in some places with a layer of	Oaken piles 1.60 m. long at distances of 2 m., on which a triangular belt of creosoted pine wood. Be-	fl. 4.60	The protection was effected in the years 1888—1890 and keeps in good condition. The

Number of the Plate.	Canal.	Nature of the ground in which the canal is excavated.	Description of the bank protection.	Cost per metre in length.	*Remarks.*
		peat 0.50 m. thick.	hind the piles a pine plank 0.28 m. high to keep the earth in position. On the tie a brick wall at an incline of $^3/_4$ in 1 without mortar above which the slope is formed with turf.		piles are, however, too short and the ground begins to wash away under the planking. It is to be feared that the protection will in time prove insufficient.
Pl. 10, Fig. 40.	**Drentsche Hoofdvaart,** part between Assen and Smilde.	Same as fig. 39.	Oaken piles with ties as in fig. 39. Behind the piles, however, is placed a belt against which a row of planks 1.25 m. the seams covered with *teugels*. On the tie a wall as in fig. 39.	fl. 6.70	The protection was effected in 1890 in places where the slope was too far washed away to keep in position with one single horizontal plank.
Pl. 10, Fig. 41.	**Meppelerdiep,** lateral branch near Meppel.	Sand.	Pine piles 2.50 m. long at distances of 1 m. at an incline of ¼ in 1. On the piles a tie and behind the piles a plank 0.25 m. high, for keeping back the earth. All of pine wood. On the tie a brick wall built without mortar at an incline of $^3/_4$ in 1 and covered with a layer of masonry. Behind the wall there is a layer of earth 0.10 m. thick and above the wall the slope is formed of turf. The height of the wall above the revetment is 1.40 m. and the protected surface per metre in length 1.75 square metres.	fl. 9.65	The protection was effected in 1891 and keeps in good condition. In a few places the wall has been damaged by collisions. On account of the great width of the canal washing out of the slope at the foot of the wall is not to be feared.

CONSIDERATION OF THE SYSTEMS ADOPTED.

We will briefly discuss the advantages and disadvantages of the different types and endeavour to draw from them sowe general conclusions.

In this discussion the fact comes prominently forward that the ground in which Dutch canals are excavated is, almost without exception, of a loose nature and liable to be washed away. Nearly all canals are cut in sand which is sometimes covered with a layer of clay or peat. A few canals, such as the Damsterdiep and the Binnen Aa in the province of Groningen, are dug entirely in clay, and in others, such as the North Holland Canal and Amsterdam—Merwede Canal, the bed partly consists of peat.

Stoney ground is only found in the neighbourhood of Maastricht on the south Willemsvaart and the Liége canal.

The conclusions which may be deduced from the examples of the Dutch canals apply therefore only to canals in loose soil.

We have already seen that the systems adopted may be brought down to a few principal types. These are however not particularly distinct from one another; on the contrary there exist intermediate forms which may be considered as belonging as well to one type as to the other.

Thus the stone talus formed of compact piles (Pl. 3 and 4, figs 7—13) may be considered as a revetment, while the brick walls without revetments and with an incline of $^3/_4$ base for 1 in height (Pl. 10, figs. 39 and 41) might also be regarded as a stone talus.

STRENGTHENED TALUS.

These are built without a wooden foundation (Pl. 1 and 2 figs. 1—6) and with a foundation of compact piles (Pl. 3 and 4 figs. 7—13).

The material used for the stone talus is generally Belgian stone, which is brought from Vilvorde and Tournay, or from the neighbourhood of Liége.

In some places broken granite is used, which is found in the district itself; while other talus are made of basalt brought from the quarries on the banks of the Rhine. Broken stone and brick from brick-fields or from demolished buildings are used to a very large extent.

The pieces of brick are about 10 ctm. × 10 ctm. × 5 ctm.

Under the layer of rubbish is, as a rule, first laid an even layer of the largest pieces.

The canals shown in Pl. 1 are canals for sea-going ships. On these canals the water can when necessary be let off to below the foot of the stone talus. On the canals shown in Pl. 1 on fig. 2 the proportion between the wet section of the canal and the submerged main section of the steamboats is so large that no real damage to the stone talus by scouring is to be expected; nevertheless it appears from fig. 2, that a sinking still occurs where the stones are not supported by a row of piles.

On the Terneuzen Canal, the only canal that is regularly navigated by sea-going steamers with a draught of 5 m., it appears that the stone talus, which extends as far as 2.20 m. below the usual water-level, sinks by the washing away of the soil at a lower depth.

The canals shown on Pl. 2, 3 and 4 serve for inland navigation. The stone talus of figs. 5, 6, 7, 8 and 9 reaches 0.40 m. to 0.85 m. below the usual water-level, whereas, on figs. 4, 10, 11, 12 and 13 it is at the most not more than 0.20 m. below the usual water-level.

It is worthy of remark that the bank protection on the Amsterdam-Merwede Canal shown in figs. 7 and 8 was built along the newly excavated sections of the canal before these were filled with water; also that on the South Willemsvaart (figs. 5 and 8—12) the water can be let off.

The talus of figs. 4, 5 and 6 is not provided with a firm foundation of piles; thus, if the slope below the stone talus be attacked by the current the ground under the talus may be washed away.

A deepening at the foot is to be remarked in all of the types presented on Pl. 2.

On canals of the type of fig. 4 it has been already found necessary to use longer piles.

On canals of the type of fig. 6, which only exists since 1892 and where the proportions of the sections are favourable, no sinking has as yet accurred.

The talus shown in fig. 5 is totally destroyed by the washing away of the slope.

It thus appears that if the stone talus be not built to a very great depth below the usual water-level, it is necessary that it be provided with a firm foundation.

On canals of the types shown in figs 7—13, which are all provided with a firm foundation, a washing away of the slope along the row of piles is everywhere visible.

The deepening is the least where the piles are placed at a considerable depth below the usual water-level (figs. 7 and 8); where their tops reach nearly to the usual water-level the deepening is very considerable and may become the cause of the leaning over of the piles and the entire work. (Figs. 10, 11, 12 and 13).

It is therefore necessary that the piles be of a sufficient length. In many places oak or pine piles are used of a length of 1.60 m. and a diameter of about 0.10 m.

These piles are much used for waterworks in the Netherlands and are known by the name of *perkoenpalen*.

They are found, however, to be generally too short to serve as supports for the talus.

In some places a second row of longer piles is placed in front of these (fig. 13), while on the South Willemsvaart for the new constructions the length of the piles used is being continually increased, and now piles of 3 m. are employed, which reach to below the bed of the canal.

If, however, such a length be given to the piles, as is done in the South Willemsvaart, we may say that the accepted type is the revetment of compact piles, and that the stone talus type has been abandoned.

The fact that the talus on the Amsterdam—Merwede Canal (figs. 7 and 8) with its foot 0.85 m. below the water-level has hitherto kept in good condition, does not yet prove that this type is sufficient for its object, as but few years have elapsed since the canal was opened for steamboat navigation.

The stone talus offers this advantage that if the slope on which it is laid sinks, it may follow the new incline without being destroyed. An example of this is given by the Amsterdam—Merwede Canal between Amsterdam and Nigtevegt (fig. 2). where the ground is of such a peaty nature and possesses so little cohesion that the slope has sunk without regard to the influence of steamboats.

REVETMENTS.

A glance at the drawings shows us that the most generally adopted type of bank protection in the Netherlands is revetment in one form or another.

The revetment may consist of a compact row of piles (Pl. 4. fig. 14 and Pl. 5 figs. 15—18, while the types already mentioned, figs. 10, 11 and 12, may be regarded as coming under the same head) or a row of planks.

The upper part of the revetment in most cases agrees with the usual water-level or is raised 0.10 m. or 0.20 m. above it.

On canals of some types the slope above the revetment is unprotected, or only provided with a bed of rushes (Figs. 14—17 and 19—25;) on others a berm is placed, protected by rubbish or stone (Figs. 18, 24, 25 and figs. 10, 11 and 12) already mentioned, by which means these types approach the mixed type of revetments with strengthened talus.

From the fact that revetment is the most frequently adopted means of protection, it must not be immediately inferred that this type is acknowledged in the Netherlands to be the best.

From the canals on which the revetments described in this report are adopted (if we except the parts of the South Willemsvaart above No. 1 lock and the Drentsche Hoofdvaart) the water cannot be let off. It is therefore a necessity that a revetment be made for these canals; unless, at least for the construction of bank protection, the canal should be pumped dry by artificial means, which would be a very costly proceeding.

Revetments have been used for years by navigation, but only after it became evident that the banks suffered serious injury from the wash caused by steamboats.

Only on the Terneuzen Canal, on which the water-level can be reduced to a certain degree below the usual level, has a revetment been adopted in the place of the system of stone talus formerly in use; while on the South Willemsvaart, where after the stone talus built previously was found to be unsatisfactory, a stone talus at a greater depth below the water level could have been easily made, of late years a system has been adopted which in reality does not differ from the revetment.

In constructing a revetment attention must be paid to the fact that the part of the wood which is not continually under water is liable to decay. The best plan would therefore be to place the wood work entirely beneath the lowest water-level of the canal; this is of course not always possible, and as a rule the upper part of the revetment is raised a few decimeters above the lowest level. In this there is a danger to the durability of the bank protection and it is not to be denied that the renewal of the piles or planks after they have become to a certain height decayed, would lead to difficulties or necessitate expensive repairs.

In some constructions an attempt has been made to counteract this difficulty by permeating the wood which is above the lowest water-level with creosote oil, in order to preserve it from decay. (Figs. 17, 20, 23, 39 and 40).

Generally, however, this is not done, but rather an endeavour is made to place the woodwork as low as possible, the consequence of which is that if the water-level of the canal varies much, the berm behind the revetment or the slope above will have to be protected against the effect of the wash of the waves.

On some canals this has been effected by planting a berm with rushes behind the revetment (Figs. 23, 24 and 25). On others the berm has been covered with rubbish or stone (figs. 26, 27) or there has been placed on the revetments a stone talus (figs. 18, 28—31) or a wall (figs. 32—41) by which is obtained the mixed type III.

Where no protection is adopted (figs. 15—17 and 19—22) it is evident that the slope above the revetments cannot in the end withstand the effect of the wash caused by the steamboats.

What immediately attracts attention in the revetments represented in the drawings is that the slope in front of the revetment which is left entirely unprotected cannot withstand the effect of the stream and of the wash and is everywhere to some depth washed away.

The soil thus loosened finds its way to the bottom of the canal and has to be removed by means of dredging in order to maintain the requisite depth for ships.

On some canals such as the North-Holland Canal (figs. 25 and 26) and the canals in Groningen (fig. 16) this deepening in front of the revetments is very considerable.

On the North-Holland Canal the deepening cannot be ascribed exclusively to the effect of the steamboats, for, as we have seen above, the ratio between the section of the canal and the main section of the largest vessels since the canal has been visited by sea-going steamers has been found very favourable.

The ground there being of peat and having very little cohesion shows a disposition to sink away to the middle of the canal.

On the canals in Groningen on the contrary (fig. 16) where this ratio is 1 : 4 the deepening must be ascribed exclusively to the working of the steamboats.

Although the deepening in front of the revetments on other canals is less considerable, it cannot be said that it has reached its limit on these canals.

The destructive effect of the stream goes on continually while, since the protection has been effected, the slope washed away is no longer filled in with soil sinking down from the higher part. Moreover, the ratio between the wet section of the canal and the submerged main section of the largest steamboats visiting the canal is not so unfavourable that if the steamboats were in reality of the dimensions admitted by the regulations, greater damage to the slope might be expected in the future.

It can thus not be said that the washing away of the slope will not occur at a greater depth than is represented in the drawings. It is as well to point out that in the newer constructions the short planks and piles of former times have been replaced by longer ones, which shows that the limits formerly allowed for the destructive effect of steamboats have been exceeded. If it be desired to build a revetment along a canal with a limited profile, prudence demands that the lower part of it be brought below the bottom of the canal or at least below the keels of the steamers of greatest draught that will navigate the canal.

The simplest form of revetment is a compact row of piles. The more complicated system consists in a row of planks supported by piles or held fast by anchors (fig. 28). It is necessary that every attention be paid to the stability of the construction.

If the revetment consists only of piles (figs. 14—16, 18 and 37) these must be selected of such length that they will not lean forward after losing their support from the slope in front of them when it is washed away.

They must, therefore, be of greater length than the depth of the canal. Where this is not the case there is danger that the revetment may be destroyed (figs. 14 and 18).

The stability may be increased by giving an incline to the piles and this is done in most cases. The incline is often 1 in 10; it may, however, be much more considerable, as in fig. 16, where it is 1 in 4 and in figs. 23, 32—35, where it is 1 in 2.

If a row of planks be used, these are supported by piles which are generally placed at a sharper incline, and which, for the reasons given above, must reach to below the bottom of the canal.

Here also it may be remarked that the piles of the older constructions appear to be everywhere too short, and that on newer constructions longer piles, even to a length of 5 m , are employed.

The stability of the revetment is sometimes also secured by iron anchors attached to piles placed farther back (figs. 25, 26, 28 and 29); in this case care must be taken that the anchor-piles are placed outside the prism of the shifting of the ground.

Anchored revetments must be regarded as the best; they are however dearer, and therefore less expensive constructions are often adopted.

An important point to be attended to in the formation of an revetment is that it should be water-tight.

When the wall is not compact, the sand behind the revetment is drawn out by the effect of the stream and the wash, and a sinking of the slope behind the revetment ensues.

Where the revetment consists of piles placed next to one another and driven in with the bark still on, there can be no question of perfect water-tightness. Endeavours have been made to prevent the washing away of the sand on these constructions, by placing behind the piles a layer of gravel (fig. 14), peat (figs. 14 and 15) or broken stone (figs. 16, 17 and 18). The application of a layer of broken stone gives good results.

If the depth in front of the piles increases and the ground behind the piles is washed away to a greater depth, the layer of broken stone sinks in and has to be filled up again from above.

The rows of piles along the South Willemsvaart have the seams between the piles filled in with stakes (figs. 10, 11 and 12); and on the Damsterdiep (fig. 34) a row of planks has since been placed behind the piles.

It is, however, evident that a perfectly water-tight revetment is not obtained in this way.

It can only be done by employing a row of planks, and this plan is also generally adopted.

When it is desired that the planks fit close, they are made with grooves (figs. 32 and 33) or otherwise planks of a lesser width called *teugels* are placed behind the seams. (figs. 24, 25 and 26).

On the constructions shown in fig. 23 partitions are applied consisting of horizontal and perpendicular planks placed over one another, which is equally effectual as regards water-tightness. On only a few constructions (figs. 20, 21, 35 and 36) are the seams not provided with planks; these do not therefore form a perfectly compact wall.

MIXED CONSTRUCTIONS.

We have seen that it is not desirable to bring the upper part of the revetment higher than the lowest water-level of the canal; the banks above, therefore, as a rule also require protection, and so we come to the mixed constructions shown in Plates 8, 9 and 10, while, likewise, the figs. 10, 11 and 12 of Plate 4 may be considered as belonging to this type. On some constructions the banks behind the revetment are protected with a stone talus of Belgian stone, brick or rubbish (figs. 11, 12, 28, 29, 30 and 31); on others the banks are given a steeper incline and a brick wall is applied.

Both types are satisfactory and it is comparatively of small interest to examine to which type the preference must be given, as the essential part of the bank protection is formed by the revetment.

It must however be remarked that in reality perpendicular walls are not met with in the Netherlands.

The steepest slope above water is $^1/_2$ on 1 (figs. 32 and 36) while the other walls have a slope of $^3/_4$ on 1. On account of this slight incline, it is not necessary that the walls be of great dimensions to enable them to withstand the pressure of the ground; the more so, as their height as a rule is not more than 0.60 m.

The thickness of the wall is never more than 0.22 m, being the length af one brick. No masonry work is used, the stones being piled on one another without mortar; with some constructions however the top of the wall is finished off with a layer of masonry.

It is seen from the drawings in figs. 35 and 41, that walls of a greater height can also be made in this way.

It appears from the above that these cannot be spoken of as revetments properly so called and that these constructions may just as well be regarded as belonging to the type of stone slopes of the brick talus type.

For the purpose of preventing the sand from washing away through the openings between the stones, some constructions have a layer of peat (fig. 36); others a layer of earth or clay (fig. 41) behind the stones.

Finally, there are a few constructions which are represented on Pl. 10, figs. 39 and 41. They are walls at an incline of $^3/_4$ on 1, which are not provided with an revetment, and may thus be regarded as belonging to the stone talus type without firm foundation.

The type shown in fig. 39, in which only one single plank is applied to keep back the earth, is not to be recommended. It appears that the ground behind the piles is beginning to wash away and it is probable that later on planks will have to be brought into requisition.

With the constructions shown in fig. 41 there exists less danger of the washing away of the bank on account of the greater width of the canal.

We have already said that it is desirable to bring the wood of the revetment to such a depth under water that it cannot rot and that thus the revetment will not require repairing later on. On a few canals this can be effected by lowering the level of the water during the execution of the work.

At the execution of the constructions presented in figs. 38—41 this result was obtained by means of small dams at equal distances from the

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centre of the canal, behind which the water-level can be lowered 0.20 m. to 0.40 m.

The expense of this damming is included in the prices quoted and amounts on an average to not more than 50 cents per metre.

COST OF SYSTEMS ADOPTED.

The figures quoted for the cost of the systems adopted must not be negarded as being absolutely correct, as local circumstances may have exercised a great influence in the cause of the expense.

Still, from these figures some comparison may be made between the cost of the different types.

The stone talus adopted on the sea-water canals (figs. 1,2 and 3) costs from fl. 13 to fl. 19 per metre in length; or from fl. 2.42 to fl. 3.30 per square metre of protected surface.

These protections reach to a depth of 1.20 m. to 2.20 m. below the usual water-level.

The revetment applied on the sea-water canals (figs. 25 to 28) of which the planks reach to a depth of 2.30 m. to 2.60 m. below the usual water-level, cost from fl. 10.50 to fl. 14.20 per metre in length.

The revetment (fig. 25) of which the planks reach to a depth of 4.30 m. below the usual water-level cost fl. 15.80 per metre in length.

The revetments, even those which reach nearly to the bottom of the canal, appear thus on these canals to be as a rule no dearer than the stone talus.

The stone slopes along the inland navigation canals, which are provided with a solid foundation at a depth of 0.85 m. below the usual water-level (figs. 7 and 8) cost fl. 5.70 to fl. 6.50 per metre in length or fl. 1.68 per square metre of protected surface.

The revetment along the inland canals consisting of a compact row of piles 3 m. in length, which, therefore reaches below the bottom of the canal (figs. 15 and 16) cost fl. 5 to fl. 7.80 per metre in length.

Where the woodwork is protected against decay by being creosoted (fig. 17) the cost was fl. 14, or nearly doubled. The revetment with planks 1.60 m. to 3 m. long and reaching not quite to the bottom of the canal (figs. 20—22) cost from fl. 7 to fl. 13.25.

The revetment with planks 1.50 m. to 2.75 m. in length, above which the bank is provided with a stone talus, (figs. 29—31) cost fl. 10 to fl. 13 per metre in length.

The revetment on the South Willemsvaart consisting of a compact row of piles 2 m. to 3 m. in length, above a stone talus (figs. 10—12) cost from fl. 2.90 to fl. 4.83.

The revetments with piles and planks 2 m. in length, above which a wall of brick is built (figs. 32, 33, 34, 36 and 37), cost from fl. 7.40 to fl. 9.10 per metre in length.

A similar sort of revetment with planks 1 m. in length (figs. 38—40) cost fl. 6.60 per metre in length.

The type last referred to, which keeps in good condition, appears to cost about fl. 3 less than revetments of the same length above which a stone talus of a lesser incline has been placed.

The protections on the South Willemsvaart consisting of a compact row of piles with a stone talus up to the present has kept in good condition, but offers nevertheless less security against the washing away of the ground behind than the planking systems do and is the cheapest of all the systems described.

CONCLUSIONS.

Notwithstanding that it is apparent from what has been said above, that we are still in the experimental stage in regard to the protection of canal banks and that we must for this reason be careful before drawing at present any definite conclusions, it will still be useful to reconsider what experience has already taught us concerning the two principal systems, viz. the protection of the original talus, or the building of new and steeper walls.

When the formation of a bank protection along a canal has been resolved upon, a choice has to be made between the two principal systems and a decision arrived at as to which is the more worthy of preference.

Further, it has to be considered to what depth below and what height above the usual water-level the protection of the canal shall be carried.

If the banks of an existing canal, of which the water-level cannot be considerably lowered (as is the case on most of the canals in the Netherlands) have to be protected we are naturally led to the revetment of the slope below water. What is done above water, whether it be a steep wall or a slope, is of less consequence, as the principal part of the construction is formed by the revetment.

On an existing canal from which the water can be let off the choice is left open; and here the preference will also have to be given to a revetment, unless the width of the canal is very wide in proportion to the vessels expected to navigate it.

The existing canals are, as a rule, enclosed between roads or cultivated land, so that a widening of the surface of the water is not possible, or it would necessitate great expense for the purchase of land. By means of a revetment the opportunity is presented of at once enlarging to its maximum the width of the bottom of the canal, by which at the same time great facilities are afforded to navigation and the ratio between the wet section of the canal and the submerged main section of the vessels is increased.

In case it should not be desirable to bring the bottom of the canal to its maximum width the opportunity remains of doing this later without injury to the banks, which would be impossible if the original slope under water had been covered with stone.

It is only necessary to see in the first place that the piles and planks of the revetment are of sufficient length, which can be effected without incurring very great expenses.

Only on canals for the service of sea-going vessels, to which a depth of 6 m. to 8 m. must be given, is any considerable expense incurred in providing their banks with a revetment, of which the planks and piles reach to below the bottom of the canal.

On these canals it is preferable to endeavour to lessen the damaging effect of the steamboats on the banks by giving the canal as much width as is possible.

The construction of an revetment for strengthening the banks of an existing canal has however this advantage, that it can be done without the water-level being lowered to any extent, and therefore without hindrance to navigation.

If at the time of cutting a new canal, it be desired to strengthen the banks, the choice of means becomes a little more difficult.

The fact then has to be considered that with one and the same width of the ground a larger wet section can be obtained if steep walls be adopted. If, therefore, the land through which the canal is cut be dear, it will be in any case advantageous to choose the revetment system.

In the second place, in selecting the type to be adopted, it must be considered to what depth the protection will have to extend.

Therefore it is necessary to know to what depth the working of the stream will be felt on the banks if a canal is navigated by steamers of the largest admissible dimensions at the greatest admissible speed. As already said above no complete observations concerning this point have been recorded and an exact figure cannot be named.

From the examples given of Dutch canals which have never been navigated by steamboats of the maximum dimensions it can however be inferred that the depth at which the effect of the steamboats is felt is very considerable, and that so long as no more exact figures are known it would be acting very imprudently if the strenthening of the banks of canals of limited dimensions was not brought down to below the bottom of the steamboats of deepest draught, and thus generally to the bottom of the canal.

If the revetment system be selected there is no great difficulty in going to this depth.

All that is required is that piles and planks of sufficient length be used, which incurs only a limited increase of expense. If however a strengthening of the original banks of the canal by means or a stone talus at an incline of 2 on 1 be chosen, and it is desired to continue the strengthening to the bottom of the canal, two difficulties arise.

In the first place, the expense increases for every decimetre deeper that we go in the ratio of 1 : $\sqrt{5}$, and is thus much more considerable than for a revetment; and, in the second place, it is impossible after the stone talus is once established give afterwards to the canal a greater depth or width at bottom without breaking up or renewing the entire work.

If, therefore, the possibility of later on enlarging the canal is necessary, the revetment system must be chosen.

If it be certain that the accepted profile of the canal will in the future be always sufficient and that no enlarging will ever be necessary, then the choice between a strengthened talus and a revetment is merely a question of expense.

A stone talus reaching nearly to the bottom of the canal is generally dearer than a revetment, as may be gathered from the examples of the Dutch canals.

But the strengthened banks offer this advantage that the banks of the canal remain unchanged and that no filling up of the bottom by soil washed away from the banks is to be feared.

We have also the choice of a mixed type by finishing off the banks where they are strengthened with a stone talus at a certain distance below the water-level with a solid wooden foundation.

It is necessary to see that the foundation is compact, and if the bed under the foundation is eventually washed away, to take care that the latter and with it the entire stone talus does not sink.

If these conditions be not fully complied with by making the piles and planks to reach below the bed of the canal, the construction may lead to great difficulties, as the restoration of the sunken bank would be very expensive and not possible unless the water be let off.

These mixed types have been found so far very satisfactory on the Dutch canals.

If a revetment is once employed as support to the stone talus there is no reason why the former should not be made to reach to a little below the lowest water-level, in which case we again come nearer to the pure type of revetment.

So, as we have already said, the revetment if it is to be lasting must be so laid that it is always covered with water. The slope above the embankment must however in some way or other be protected against the effect of the wash of the water. The material used for this purpose is stone in the form of either a stone talus or of a more or less steep wall.

On canals where the water level does not vary much, the question whether a talus or wall should be made above the revetment is of comparatively small importance, as it is only necessary to give an inconsiderable height to the protective works and the difference in the cost is thus very small.

Local circumstances will here in most cases decide the question;

still the point should not be lost sight of that on canals with steep walls it is more difficult to reach the water from the banks.

On canals where the water-level varies very much, the protected slope above the revetment, which is below the lowest water-level, must have a considerable height.

In this case an almost perpendicular wall would have to be of great width in order to offer resistance to the pressure of the ground, and the contruction of a stone talus on the natural slope would as a rule be cheaper and better.

It should be remarked that on the Dutch canals there are no perpendicular walls placed above revetments. The steepest slope there is still $^1/_2$ in 1 and that on canals which are cut in clay soil. For those in sandy soil an incline of $^3/_4$ on 1 is given to the wall.

We have still to consider to what height the strengthening of the banks must be effected.

On canals with a fixed water-level we must examine to what height the waves caused by the steamboats rise and the protection must be carried above this height.

If the high water level on a canal only lasts a few days, it will not be necessary to make the protection of the bank reach above this highest level.

It will generally be sufficient if the protective works be brought so high that it reaches above the wash of the waves caused by the steamboats at the usual highwater level.

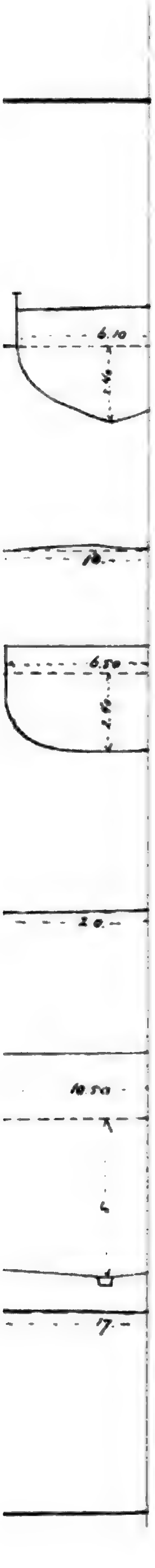
On the Dutch canals these works reach as a rule 0.40 m to 0.60 m. above the usual water-level and 0.15 m. to 0.30 m. above the highest water-level.

It is, however, in most cases of secondary consideration to determine beforehand to what height above the water-level the protection must reach, as it will be little trouble to make the construction higher, whether it is a stone talus or a steep wall, if it should appear that the height first determined on be insufficient.

April 1894.

Translated by G. J. Rowland.

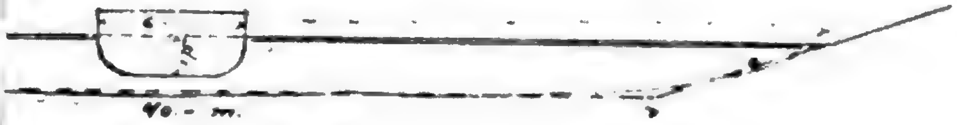
Inscriptions des Planches.	Inschriften der Zeichnungen.	Description of the Plates.
Argile.	Thonerde.	Clay.
Briquaillons.	Steinschutt.	Brickbats.
Briques.	Backsteine.	Bricks.
Echelle.	Maasstab.	Scale.
Empierrement.	Steinschüttung.	Stone-ballast.
Enrochement.	Felssteinpackwerk.	Enrockment.
Espacé de	In Abständen von	At a distance of . . . . .
File dé pieux.	Pfahlreihe.	Line of piles.
File de piquets.	Pfahlreihe.	Line of stakes.
Gazons.	Rasen.	Sods.
Glaise.	Lehmiger Boden.	Clay.
Gravier.	Grand.	Gravel.
Les bateaux à vapeur ne visitent pas le canal.	Dampfschiffe benutzen den Kanal nicht.	Steam-boats do not enter the canal.
Madrier.	Eichenholzbohle.	Joist.
Moise.	Gurtholz.	Half-timber.
Niveau d'été.	Sommerwasserstand.	Summer level.
„ d'hiver.	Winterwasserstand.	Winter „
„ ordinaire.	Gewöhnlicher Wasserstand.	Ordinary „
„ réglementaire.	Vorschriftsmässiger Wasserstand.	Regulation „
Palplanche.	Bohlenwand.	Walling-timber.
Perré.	Steinpackung.	Stone-pitching.
Pour le profil en travers du canal, voir	Für den Kanalquerschnitt siehe	For the transverse section of the canal, see . . . .
Revêtement en planches.	Bekleidung mit Planken.	Revetment of planks.
Roseaux.	Rohrpflanzung.	Reeds.
Section immergée du bateau.	Eingetauchter Schiffsquerschnitt.	Immersion of the boat.
Section mouillée du canal.	Benetzter Kanalquerschnitt.	Wet section of the canal.
Tirant.	Ankerbolzen (Zugeisen).	Truss-rod or tie-iron.
Tourbe.	Torf.	Turf.
Tringle.	Leiste.	Rod.
Tuin.	Hecke.	Hedge.


6.10
2.40
10.
6.50
2.60
20.
10.50
4
17.

Pl 2.

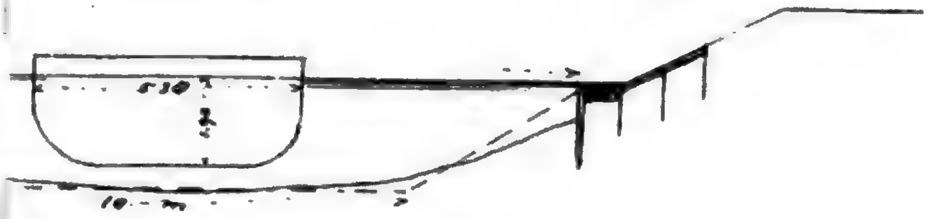
Echelle de 1/400

$$\frac{S.i}{S.m} = \frac{9.4\,m^2}{113\,m^2} = \frac{1}{12}$$



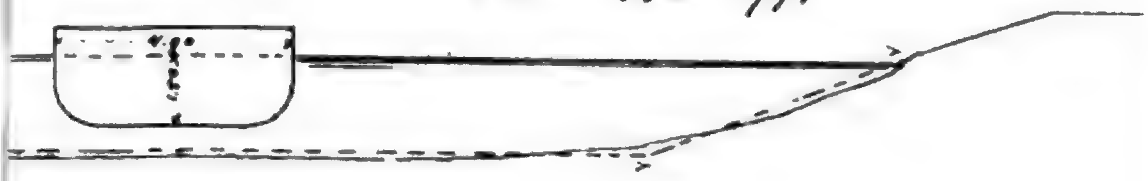
Echelle de 1/200

$$\frac{S.i}{S.m} = \frac{9.8\,m^2}{30\,m^2} = \frac{1}{3.06}$$



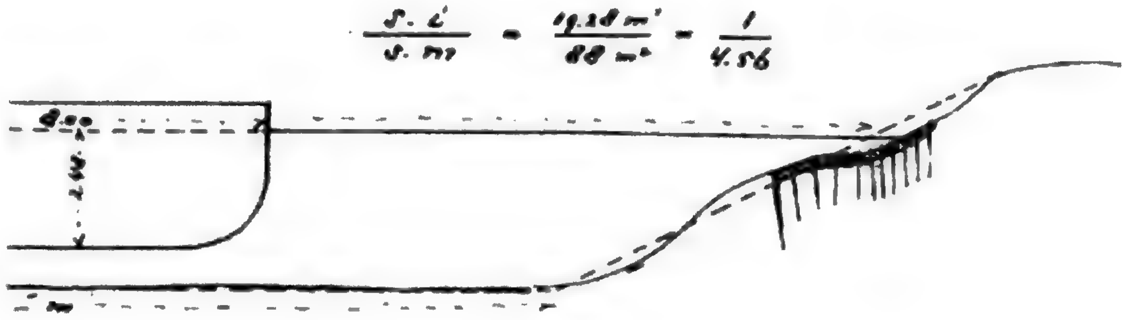
Echelle de 1/200

$$\frac{S.i}{S.m} = \frac{6.85\,m^2}{53\,m^2} = \frac{1}{7.74}$$



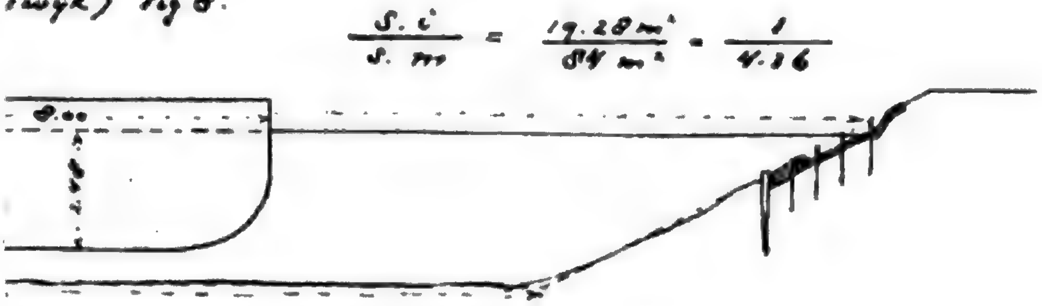
Pl 3

7

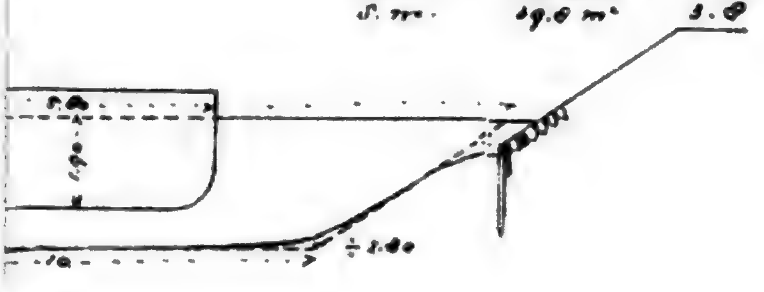


$\frac{S.\ i}{S.\ m} = \frac{19.28\ m^2}{88\ m^2} = \frac{1}{4.56}$
8.00

…wgk) Fig 8.



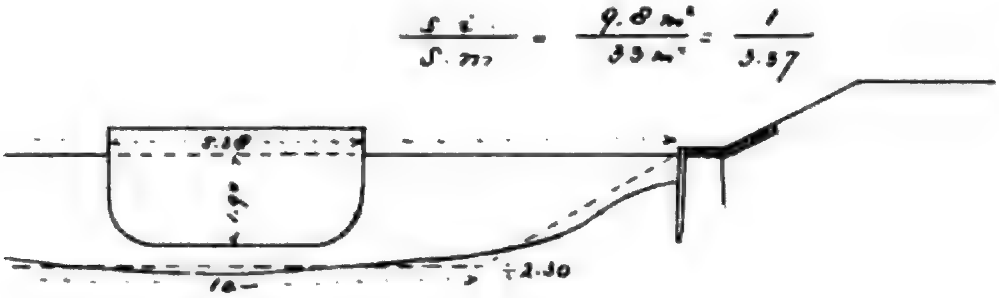
$\frac{S.\ i}{S.\ m} = \frac{19.28\ m^2}{84\ m^2} = \frac{1}{4.36}$
8.00



$\frac{S.\ i}{S.\ m} = \frac{10.45\ m^2}{39.8\ m^2} = \frac{1}{3.8}$

Echelle de 1:200.

Pl. 4.


$\frac{S.i}{S.m} = \frac{9.8\,m^2}{33\,m^2} = \frac{1}{3.37}$
5.10
10 –
÷2.30

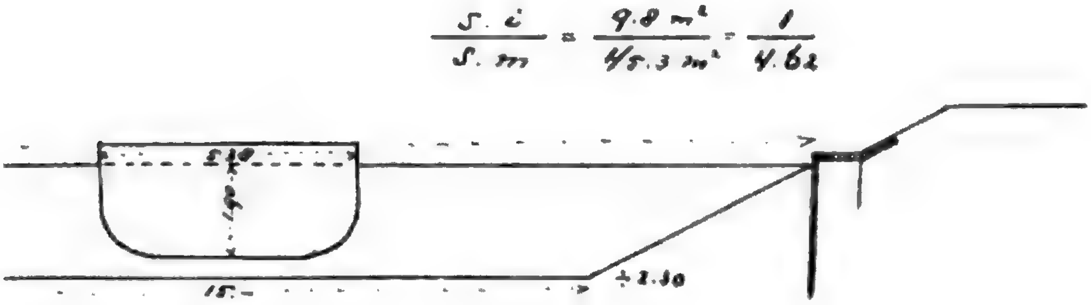
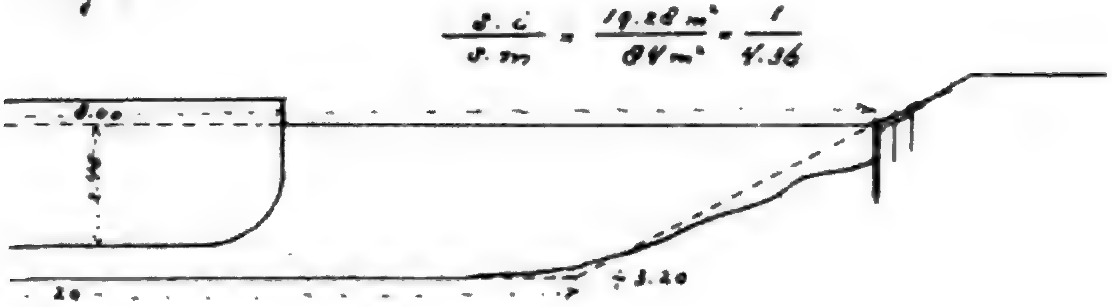
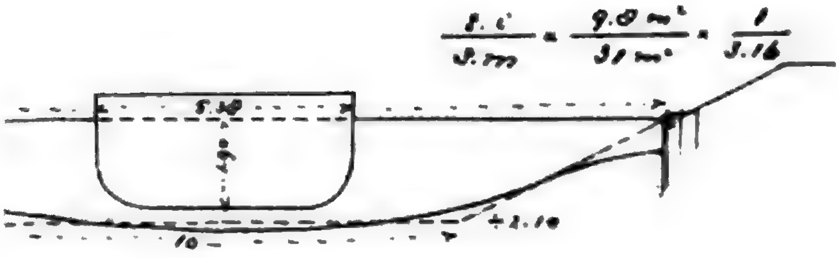

$\frac{S.i}{S.m} = \frac{9.8\,m^2}{45.3\,m^2} = \frac{1}{4.62}$
5.10
15.–
÷2.30

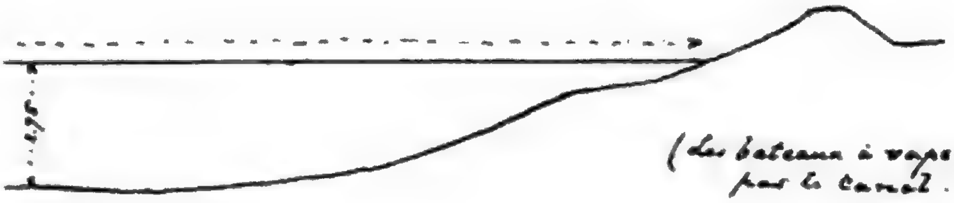
Fig 13.


$\frac{S.i}{S.m} = \frac{19.28\,m^2}{84\,m^2} = \frac{1}{4.36}$
8.00
20
÷3.20


$\frac{S.i}{S.m} = \frac{9.8\,m^2}{31\,m^2} = \frac{1}{3.16}$
5.10
10 –
÷2.10

Echelle de 1:200

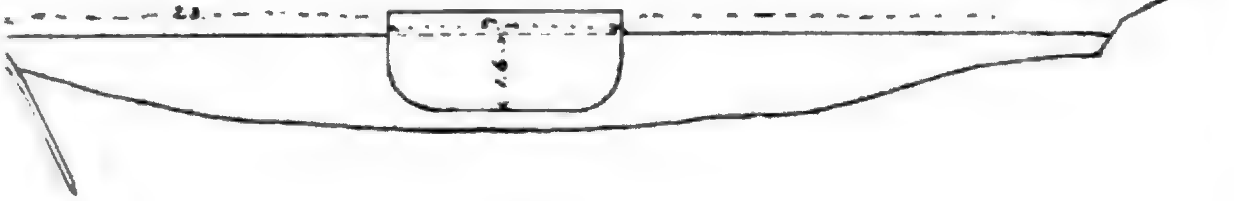
Pl. 5



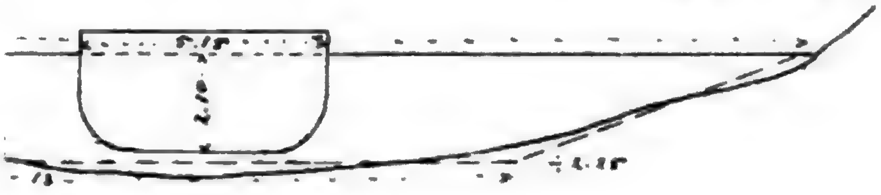
(Les bateaux à vapeur ne visitent pas le Canal. Fig 17

Groningen à Lemmer. (partie de Stroobos à Gerkesklooster)

$$\frac{S.c'}{S.m} = \frac{7.6\ m^2}{34.5\ m^2} = \frac{1}{4.54}$$



$$\frac{S.c'}{S.m} = \frac{10.27\ m^2}{44\ m^2} = \frac{1}{4.28}$$

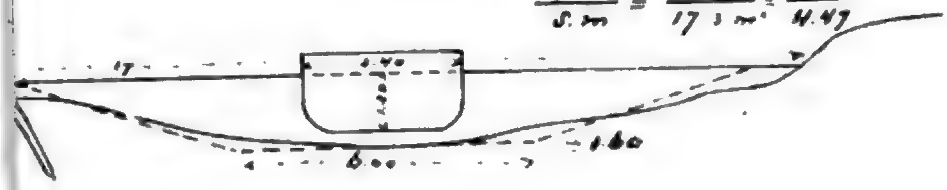


Échelle de 1:200

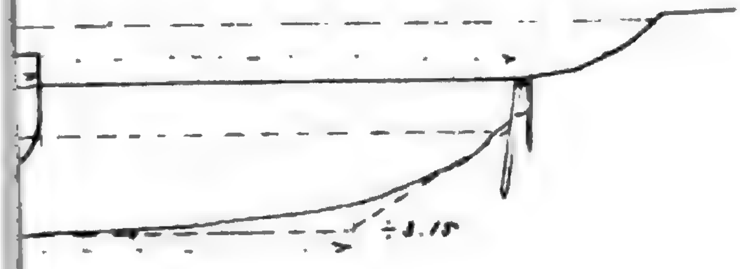
Pl. 6

à Gerbenallesvertaat Fig 20

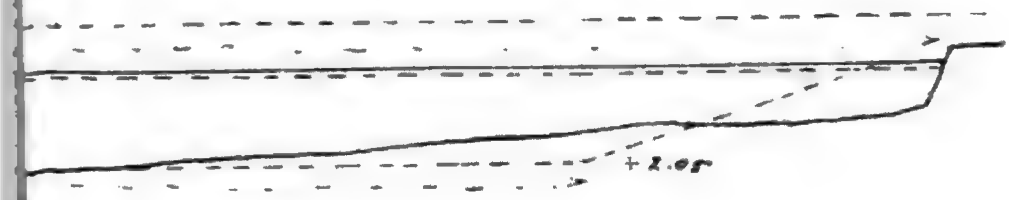
$$\frac{S.\,i}{S.\,m} = \frac{3.87\,m^2}{17.3\,m^2} = \frac{1}{4.47}$$



$$\frac{S.\,i}{S.\,m} = \frac{9.35\,m^2}{63\,m^2} = \frac{1}{6.73}$$

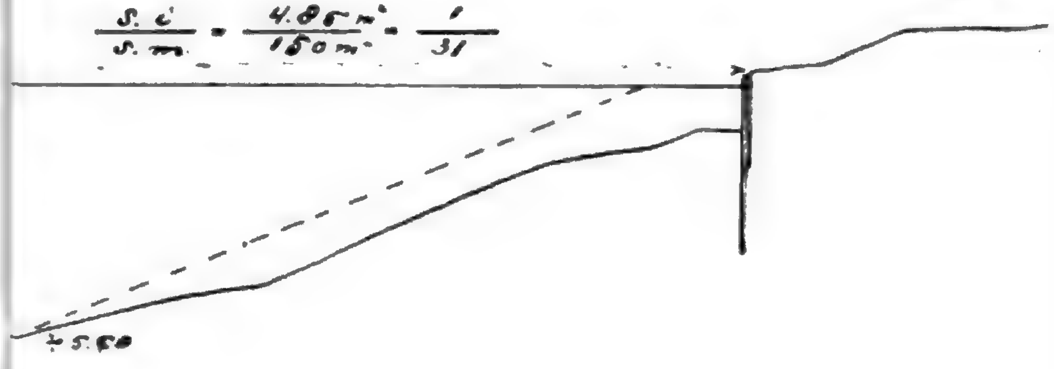


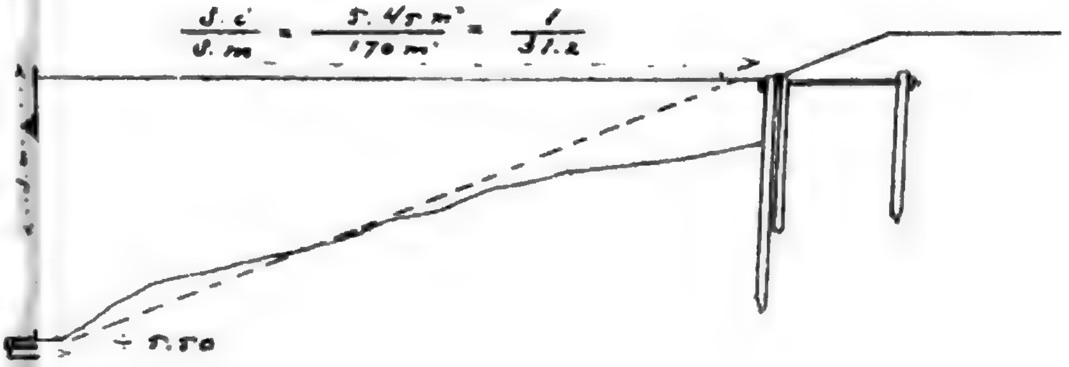
$$\frac{S.\,i}{S.\,m} = \frac{6.85\,m^2}{65\,m^2} = \frac{1}{9.5}$$

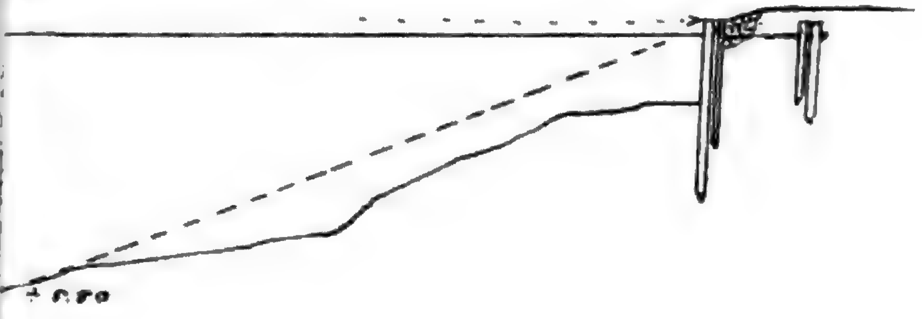


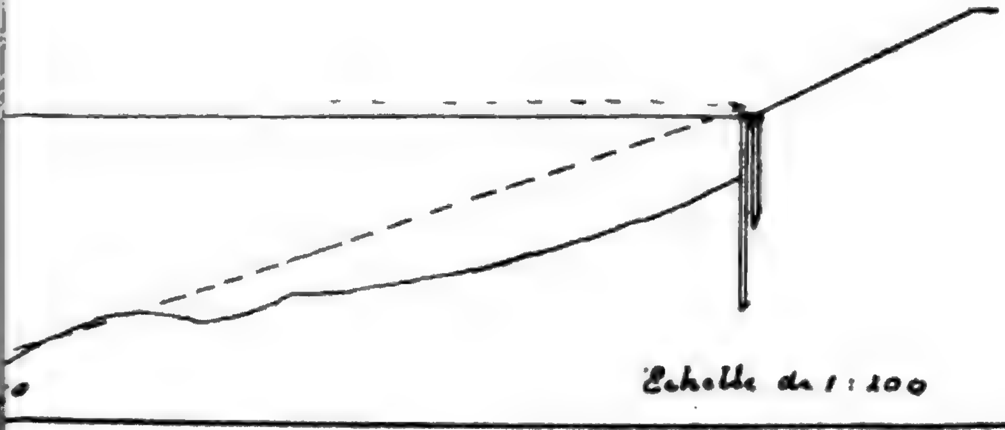
Échelle de 1 : 200

Pl 7





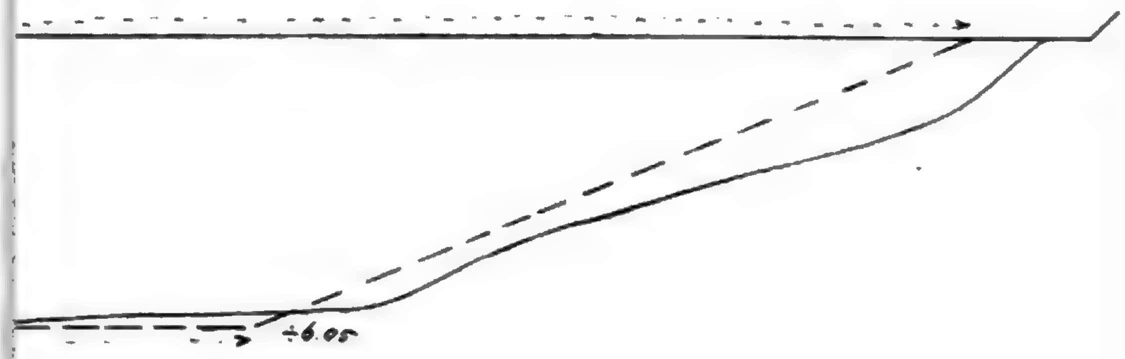


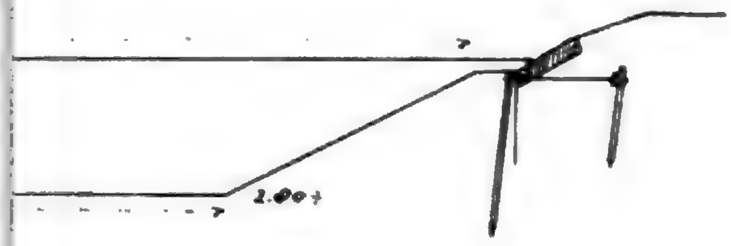


Echelle de 1:200

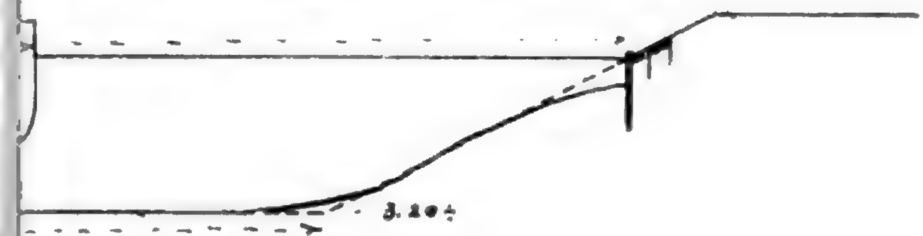
Pl 8

$$\frac{s.i}{s.m} = \frac{50\ m^2}{225\ m^2} = \frac{1}{4.5}$$

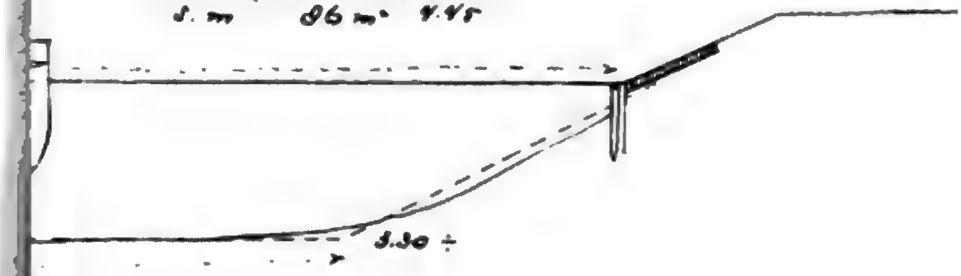




$$\frac{s.i}{s.m} = \frac{19.28\ m^2}{84\ m^2} = \frac{1}{4.36}$$



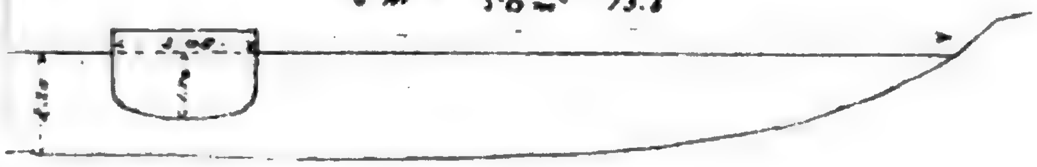
$$\frac{s.i}{s.m} = \frac{19.28\ m^2}{86\ m^2} = \frac{1}{4.45}$$

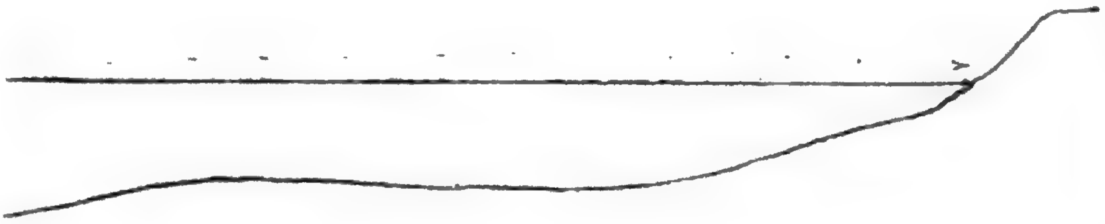


Echelle de 1:200

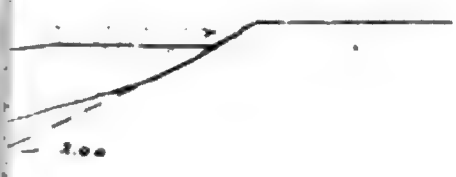
Pl 9

$$\frac{S.c}{S.m} = \frac{4.2\,m^2}{56\,m^2} = \frac{1}{13.3}$$





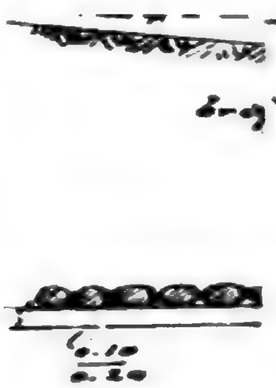
$$\frac{S.c}{S.m} = \frac{7.60\,m^2}{34.50\,m^2} = \frac{1}{4.54}$$

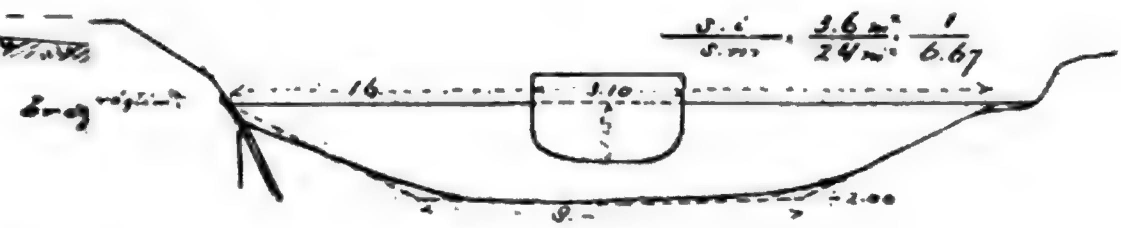


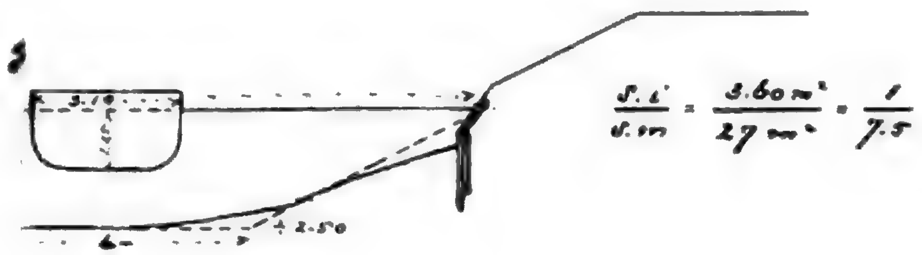
Echelle de 1:200

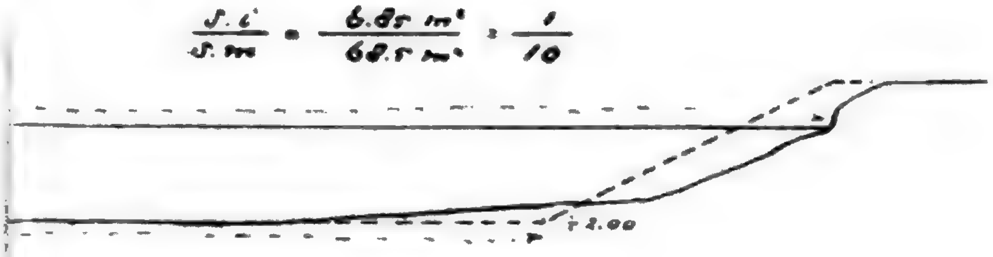
Pl 10

sche Hoofdvaart Fig 38









Ea

Echelle de 1 : 200.

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Steendr. v/h. Amand, Amst.

4

VIth INTERNATONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

2nd QUESTION.

THE PLANT OF FRENCH INLAND NAVIGATION PORTS.

REPORT

BY

A. MONET,
Ingénieur des Ponts et Chaussées, Nancy,

AND

E. DARDENNE,
Ingénieur des Ponts et Chaussées, Paris.

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THE PLANT OF FRENCH INLAND NAVIGATION PORTS.

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A. MONET,
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CHAPTER I.

General Considerations.

Definition of the Plant of Ports.

The plant of inland navigation ports comprises all the different services and appliances used in its working, except such as form integral parts of the ways and communications.

Public and Private Plant.

The plant of a port may belong to two distinct categories: it may be public or private.

It is said to be public when the public have at a fixed rate a perfect and inalienable right of use of it under certain determined conditions, no matter who is the owner, whether the state, the town, a company or a private individual.

It is private when it is put up for private use, whether on privately owned sites, or on the premises belonging to the public navigable waterway with the requisite special authorisation.

In certain circumstances private plant may, by an understanding with a third party, render the service of public apparatus, but it is evident that this would not give it a public character in the precise and definite sense attached to this word.

Conveyance of Passengers and of Goods.

Navigable waterways may serve for the conveyance of passengers as well as for merchandise.

For passengers special accomodation in ports is necessary; but this concerns rather the waterways than the ports properly so called, and will not here be treated of. It is with the accomodation and appliances for working the goods traffic and carrying trade that we shall occupy ourselves.

What constitutes the plant of a port.

A port must in itself and by its existence offer certain accomodation to and form an integral part of the navigable waterway; it completes the channel of transit placed at the convenience of the public. The accomodation includes docks, wharfs and quays and their moveable and immoveable accessories such as connecting lines of rail, quay space, moorings and the various conveniences and adaptations for handling traffic. All these were discussed and treated of at the Manchester and at the Paris Congresses, but the plant falls under a distinct and separate head and should not be confounded with them.

The plant includes all mechanism, material and services organised in view of a rational and effective use of the port itself.

To roughly define without strict limitations we mention the following as being the principal elements which constitute the plant.

1. The lines of rail specially laid to bring or take cargo to or from the port forming its connecting link with inland railway systems, or with private or other workshops, yards and factories.

2. The sheds and warehouses, whether built on the open spaces or on the quays for the temporary storage of goods, warehousing or sorting and repacking, transit and forwarding or where they remain while awaiting to be bonded (1).

3. The apparatus and appliances of every kind for the easy and expeditious handling of goods and packages, special jetties and stages, all

---

(1) In speaking of sheds and warehouses, they should be divided into the following classes:

(*a*) Open sheds to serve as a temporary cover during the process of grouping, classing and arranging of out-going or in-coming cargo.

(*b*) Closed sheds in which goods may be placed temporarily before departure or after arrival in port.

(*c*) The *entrepôts* or general warehouses.

stationary, moveable or other cranes, lifts, trollies, shoots and automatic loading apparatus (1).

Distinction between Public and Private Ports with regard to their Plant.

As already said a distinction must de made between public and private plant.

So also the ports themselves may be public or private, according as they are for general public use and form part of the navigable waterway, or are formed by and for the exclusive use of private firms or individuals.

The plant found in private ports has its own special character, and is not available for public use except under extraordinary circumstances.

In public ports there is a preponderance of public plant. Private plant must there be subjected to public interests and must not be allowed to form an obstacle to these interests. Restrictions must be imposed in favour of these latter.

Thus it will be seen that though there is not absolute correlation between public and private plant of ports on the one hand, and public and private ports on the other hand, each of them corresponds to distinct needs. It may be affirmed that there is a very different character presented by each. Each must therefore be studied apart, in reviewing the plant of public and of private ports.

In France on most of the largely frequented waterways the transport of manufactures forms at present the main item. The firms interested have generally been induced to fit out, often with excellent and powerful plant, their own private ports. On the other hand the public ports, either on account of absence of traffic or from want of initiative on the part of those most interested, are often very badly, if it all, provided with loading and other appliances.

Consequently the plant of private ports is much more advanced and better understood than that of public ports; for this reason let us first look at the first named, and with regard to the second we will afterwards go into the question fully.

PLANT OF PRIVATE PORTS.

Its nature.

As to the private industrial or commercial ports, those interested are free to put down such plant and organise such service as they may deem necessary and convenient;

---

(1) It is well to mention especially the engines which are indispensable for the handling of goods and packages of exceptional size and weight which cannot be landed or shipped without the help of these engines.

1. So long as this does not infringe nor encroach upon public rights of way, security or working facilities.

2. When in so doing no public ground is utilised for private purpose nor affected as regards its position.

In establishing plant as well as in forming the port itself these two conditions are not always observed; but to put up plant on any part of the navigable waterway or its adjoining ground-space authorisation is necessary.

Although these private encroachments are contrary to regulations, so long as proper precautions are taken it may be advantageous to tolerate them; a rent and right of expulsion must however be exacted; also the authorisation must be subject to conditions which safeguard the public interests, especially the liberty and security of circulation both on the tow-path and on the navigable waterway. Outside these reserves the authorisation accords to the holder full liberty of action in the arrangement of his plant.

In imposing restrictions the local conditions will be taken into account; in one case the private port may be a simple widening and siding in the navigable waterway, and in another case there may be one or more basins connected with this latter. In this case the connecting channel or link will mostly run through property outside the limits of main waterway, and this and the private dock arrangements and appliances are private property and as such free from restriction.

In the other case there is usually a tow-path which must not be obstructed; hence certain imposed conditions touching the disposal of plant.

Character and Purpose of the Plant.

The aim and purpose of all apparatus is to increase the working capacity of the port, and to reduce cost of labour. To this end the general and essential conditions to be fulfilled are the following:

(*a*) *For unloading:* direct transferring of goods from the ship to the vehicle which is to deliver them at the works where they are to be used, or into the warehouse or other storage place, which should be as conveniently situated as possible.

(*b*) *For loading:* taking goods as far as possible at the place of production and passing them on for direct shipment on board the boats.

These conditions are more or less completely fulfilled in different ports by means of machines which differ greatly according to the establishment and industry or to the kind of material usually received or despatched, and to the distance between the place of production and the port.

For unloading: manual cranes, steam cranes, pneumatic and the electric cranes are most generally used.

The crane is sometimes fixed and sometimes travels on rails laid parallel to the quay-walls.

For fine material for which shovels can be used, baskets are often employed which when filled are passed on to trucks on the quay.

When the working space allows of it, it is well to give the crane sufficient reach to load from the ships' holds to the truck direct. Under certain conditions it is advantageous to substitute for cranes other appliances, such as blocks, pulleys, shoots etc.

The most usual means of transport are narrow guage railways for small waggons and trucks, and an ordinary guage for the ordinary railway truck for carrying goods any considerable distance.

It is impossible to definitely fix the position to be occupied by the crane with regard to the quay service lines of railway and for the sidings provided in most well-formed ports. The number of direct loading and shunting lines may vary to suit special requirements.

For loading: the same means are generally used as for unloading, especially when heavy goods and packages requiring care are to be handled. For goods that can stand rougher usage and are unlikely to be injured by knocks or falls the simpler system of tipping is reverted to. By means of suitably arranged hoppers or falls, the contents of the tipping truck or other vehicle is discharged either directly into the boat, or along the more gently sloping shoots to avoid undue breakage or pulverisation.

As for unloading, the arrangement of service railways will vary to suit the necessities of the trade of the port and no fixed plan can be suggested.

Most manufacturers and owners of works have their establishments in connection also with the railway system, but generally their train and canal services are distinct and independent. Certain emporiums however have the two services connected for the sake of transhipment or the transferring of merchandise from the waterway to the railroad or the reverse. This convenience however is for public rather than private ports and we shall have to return to the subject later.

Private ports at a distance from the works they are intended to serve and connected with them by rail are in reality transhipment ports analogous to those to be studied later. Here we simply mention them.

Economy in the equipment of ports consists especially in the easy and perfect connection between the port generally and the plant for manipulating material inside the factory or works.

The aim in all cases is to bring the material to the point and level required as economically and with as little handling as possible. Each case has its own exigencies and is subordinate to its own special considerations and circumstances, and this makes difficult if not impossible the comparison of results by any particular system. Certain special considerations may even cause the sacrifice of any advantage to be gained by adopting modern or apparently improved systems; as in the case of the Blanzy mines, where the company have hitherto not found it in their interests to equip with modern plant their port of Montceau les Mines; the 400,000 tons of coal shipped there are moved almost exclusively by hand. Similarly the port of Bois-Bretoux belonging to the Creusot works is by no means provided with plant in keeping with the 250,000 tons annually manipulated there; there are 15 travelling and 6 stationary cranes, but most of them are of old pattern and worked by hand. A large part of the goods handled, instead of being transferred directly from railway-truck to boat, or inversely, is first warehoused and removed afterwards without cranes (1).

The Montluçon ports, including the private port of the Commentry-Fourchambault Company where the tonnage was in 1892 over 600,000 tons, and in 1893, 458,000 tons (of which 200,000 consisted of coal), have a comparatively limited plant; about one half of the total tonnage is moved by hand.

In short it may be affirmed that in private ports the plant for loading and unloading is so varied that any comparison on general principles is impossible.

Under these circumstances we have simply tried to shew how the different questions relating to the plant of private ports have been or may be met. To this end we have described in a cursory manner the equipment of certain ports on the inland waterways of France, which by the importance of their traffic and the system adopted seems to merit special notice.

In Chapter II will be found a short account of:

A. Coal-loading plant in use in the coal fields of the department of the Nord and of the Pas de Calais;

B. The plant at the port of Montceau les Mines, (Blanzy Mining Company);

C. Plant at the port serving the Forges et Hauts-Fourneaux (Works and Blast Furnaces) at Marnaval, Haute Marne; and at that used by the works and foundry at Neuves-Maisons (Merthe and Moselle Canal de l'Est); also of the plant in the ports belonging to the Société de St. Gobain at Chauny (Oise), and of the port created by Mr. DARBLAY (Essone paper mills) at Bas-Vignons near Corbeil.

PLANT OF PUBLIC PORTS.

Its nature.

A puplic port should, as we have already said, be equally free to all and without privilege for anyone. In general its apparatus too should be public property. There are however, even on the French navigable waterways, somewhat numerous exceptions to this rule.

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(1) See the plan of the port of Bois-Bretaux. (Pl. V).

It has in fact been recognised that under certain circumstances it is well not to refuse to manufacturers, especially those whose works are adjoining the waterway, the permission to establish plant in the public port, provided that public interests are not thereby injured nor any monopoly acquired. Permissions thus granted are however always revocable. It is expressly stipulated that no privilege such as the special or first use of the quay and moorings for his wares and boats is by that means accorded. The administration requires that all roads shall be unobstructed; that all space except that on which the appliance stands shall be exclusively for the use and handling of goods carried or to be carried by their waterway; they shall be subject to all the existing or prospective laws and bye laws.

As a general principle the administration of the French navigable waterways requires that all public plant not provided by the State shall form a subject for enquiry and a decree of authorisation shall be rendered previous to its adoption. There shall be annexed to the concession a fixed maximum scale of charges to the public for the use of it.

We must add that this rule has not always been absolutely adhered to. There are on our waterways a rather large number of appliances for which a simple licence has been obtained, stipulating that the use of the plant shall be had by the public at certain maximum charges, which sometimes correspond with the local tariff.

Under the present administrations these restrictions and these concessions are practically insufficient and the administrative control is uncertain. Still the revocability of the authorisation justifies the liberty taken with the rights of the State and the township.

The services to be rendered to the public by the plant are also in their favour, but they might be sacrificed were formalities of too complicated a character rigourously insisted upon.

In a general way this plant is useful to all, to the owner because they save charges on the one hand, and on the other hand to the public because it ensures rapidity of work and a better utilisation of quay space.

Restricted Development of Public Plant.

In French public ports plant in general, but especially public plant has hitherto been but very little developed. The plant actually existing is in fact almost nil.

Railways. The lines connecting ports with the railway systems of the country are not numerous. Some of them were built by the State either when the main line and the navigable waterway were constructed and were in some cases amalgamated with the main line on its being leased to a company. The few lines of this class still forming part of the public property form the only plant belonging to the state in ports.

Others have been added in the concession for new railways; and others again have been conceded either to local companies furthering general public interests, or to independent contractors.

Where handed over they are assimilated to tramways; the same conditions and the same formalities are imposed. The actually existing constitution and laws of the large companies does not now allow of new connecting lines with the waterways being added without a special concession. On connecting branch lines the companies owning them generally provide and supply waggons and trucks to private merchants on the same conditions as at stations on their main line. Also as in these stations they reserve to themselves the manipulation of certain classes of goods and leave to the marchant the handling of others at general rates fixed without reference to certain special conditions favouring transhipment.

In the greater number of cases the special tariffs which favour commercial transactions, or at least make them possible, are not extended to the connecting branch lines.

On such of these latter as are not owned or worked by the larger companies, in the absence of some special arrangement, trucks and waggons are sent to the junction of the two lines, and for goods carried each line makes its own separate charges; this has an injurious effect on the development of the port.

The number of French public ports having railway connection is anything but large. With 12000 kilometres of navigable waterway the number of connecting lines falls short of 70 and the tonnage carried by these is insignificant; tariffs kept purposely high by the railway companies, the almost complete absence of cargo-handling appliances, and too frequently the bad condition of the port itself (especially when the waterway belongs to the railway company), all check the development of the port.

Even the plant of the Paris ports and docks is absolutely primitive. The Javel branch it is true carries a certain amount of traffic in spite of the fact that the railway company which constructed and still works it charges an additional fr. 0.30 per ton. The branch line of Conflans (the general warehouses of the port of Bercy) is worked privately and is provided with 2 cranes for transferring goods from rail to boat at the rate of from fr. 1.50 to fr. 2 per ton to cover the railway charges and cost of maniputation.

At the Saint-Ouen Docks which are connected by rail with the Northern Railway, the Dock Company's charges for use of cranes and waterway (fr. 0.30) are on an average fr. 1.50 per ton.

On the Paris-Lyons-and-Mediterranean Railway route there are about twenty basins which have railway connection; at least two of these (Givors and Lyon-Perrache) might have commanded considerable traffic and development had not the plant been neglected by the P. L. M. Company. At Lyon-Perrache the charges are excessively high, besides a fixed sum of fr. 10 and a charge of fr. 0.50 to fr. 1 per day on the boat, there is a further branch tax of fr. 0.12 per ton charged on the merchandise. The station proper is open for goods for or from the Bourbonnais or the Cette districts exclusively.

The Dijon, St. Jean de Losue, Besançon and Chagny branch lines are more accomodating, although fr. 1 (or fr. 0.50) per loaded truck is charged in either direction. On the other hand the growth of the port and traffic has for years past been paralysed by the excessive rates imposed by the company; these vary from fr. 0.10 to fr. 0.75 for goods handled by the owners and for those handled by the company from fr. 0.80 to fr. 1.20.

On the system of the Orleans railway company, where competition from waterways is less to be feared, the management of the connecting service ports (few in number) is more satisfactory. Still here too there is an insufficiency of plant which is much felt. The canal worked by the company at Montluçon shews a tonnage carried of 50,000 tons.

On the Northern Railway system there are 10 public ports with branch lines connecting them with the main line; none of them have any plant and need no special mention.

The same might be said of the 14 public ports in connection with the Eastern Railway. Of these some belong to the Marne au Rhin Canal. They will be described later (see Chapter III).

Sheds and Warehouses. These too are of limited number on the navigable waterways of France.

At no place on the waterways have sheds been put up for in-coming or out-going cargo, or for classing and sorting the same.

No sheds, except those erected by the municipality of Paris on the Villette dock (12 m. wide and 9100 sq.m. in superficial area) and those put up by some of the large inland river carrying companies (Havre-Paris-Lyons-Mediterranean Company; Pavot Frères, &c).

Through private enterprise these render excellent service. For the most part their authorisation is revocable and they may be classed among those for which temporary licence as mentioned already above has been granted. Generally they consist of wooden sheds varying in size to suit the requirements of the trade (1).

In some instances transport companies have erected warehouses outside the waterway but still as near as possible to the channel itself. As an exemple we may mention the warehouses at Valenciennes belonging to Messrs Pavot Brothers; the building consists of cellaring, ground floor and two stories and occupies 300 sq.metres of ground space. The same firm has another warehouse at Lille of 1500 sq.m. let to the Docks and Customs there.

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(1) The H. P. L. M. Company's sheds at Dijon, two in number, and measuring 500 sq. m. may be cited. The Joigny and Commerce sheds measure 270 sq.m. and those of Orleans, Chalons, Saone and Maçon 160 sq.m. etc.

At Compeigne, Chauny, St. Quentin, Cambrai and Donai, Messrs Pavot Brothers have sheds measuring respectively 70, 150, 300, 350 and 500 sq.metres.

For the most part these entrepôts belong to private companies who work them as General Warehouses. The number of these warehouses is anything but large. We can only mention those of the Villette dock (Paris) belonging to the General Warehouse and Entrepôt Company (1); the entrepôts of the Lyon-Vaise dock and those at Lille, Tergnier, Nancy, Gray, and Montargis. Moreover we need not dwell on these private establishments whose tariffs are not regulated for the public.

Some of them have railway connection (Lyon-Vaise, Nancy, Gray). Specially arranged sidings exist in most cases to facilitate transhipments from rail to boat, but it must also be added that the contracts between the warehouse and the railway companies are not at all of a nature to facilitate these operations.

Appliances. In public ports the number of absolutely public appliances for handling goods is very limited.

The private docks and warehouses adjoining the port are for their own use provided with appliances such as cranes or other special plant for which a temporary and revocable licence is held. The carrying companies have also one and sometimes 2 or 3 cranes lifting from 1 to 3 tons generally and almost exclusively engaged in the service of their own warehouses and boats.

Except these only here and there are there any appliances for public use.

Even the ports of greatest importance have a very insufficient plant; the Lyons-Vaise dock is provided with 5 stationary canes of 1,2 and 5 tons, and with a travelling crane of 2 tons.

At Dijon there are 3 cranes lifting 1, 3 and 4 tons; at Gray 4 of 6 and 10 ton power, and a floating 1 ton crane; at Roanne we find again 4 to lift 10, 6, and a 1 ton floating crane. Montluçon has, besides 2 private 6 ton cranes and special plant belonging to the Commentry Fourchambault and the Chatillon-Commentry companies, only a 4 ton travelling crane which is on the Orleans Company's basin.

On all the docks in Paris taken together we find the following apparatus:

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(1) For the sake of precision we will also mention the Paris entrepôts specially used for wine and situated near the navigable river (Halle aux Vins; Entrepôts de Bercy), as well as the sheds built by the General Warehouses company at Conflans. Let us also mention the warehouse built by the Paris General Warehouses company close to the Seine (Quai de la Gare).

1. *On the Seine* 7 steam cranes, of which four of 3 to 4 ton lifting power belong to the Gas Company and three of 2 to 5 tons; 7 manual cranes of 1 to 4 tons, and 38 floating 1 to 5 ton cranes. Among these are not included 5 private shears nor a 30 ton crane (at the Cail works), and 2 travelling cranes for unloading building-stone;

2. *On the S^t Martin dock* eight 1 to 2 ton cranes and one of 1 ton for public use at a fixed charge; 5 cranes lifting from 6 to 15 tons for building-stone and 4 shears for private use;

3. *On the Villette dock* 6 stationary 1 ton cranes for public use without charge; also 1 fixed 1 ton and 5 floating 2 ton cranes for public hire. Besides these there is one 10 ton crane for handling building-stone; 3 private 1 and 1½ ton and 1 hydraulic shears. Taken jointly the apparatus on the Villette dock serves for 27 % of the total amount manipulated, which exceeds 1,060,000 tons;

4. *On the S^t Denis Canal* outside the Paris limits are 5 cranes of 2 ton lifting power; 1 of 5 tons; 1 of 2 tons; 2 shears to lift 20 and 35 tons respectively which can be hired by the public; also 2 private 8 to 10 ton cranes.

As we have seen, Paris possesses a somewhat considerable number of powerful cranes and derricks for handling building-stone or for heavy machinery. Most of these appliances may be hired by the public.

These powerful machines are uncommon on the French navigable waterways and are for the most part the private property of quarry-owners, who have provided them and who use them for embarking building-stone.

This paucity of apparatus is to be regretted. Yet it must be admitted public initiative can scarcely be counted upon for the providing of this class of plant which a at few given points would be likely to prove by its hire a remunerative investment. It would seem a more hopeful solution of the difficulty were floating plant to be provided capable of visiting and serving a number of different points along the same navigable waterway.

It is desirable too that in the public interest these appliances and the conditions and tariff of hire should form the subject of enquiry and special concession. Those at present in use exist in virtue of a simple waterway licence.

To complete the foregoing general information, we shall give later on (Chap. III), after a description of some exclusively private ports, a brief account of an important waterway, the Marne au Rhin Canal, noticing both its public and its private ports. Examples of the different cases and conditions already spoken of will be found, as well as of the different appliances made use of to suit the nature of the goods to be handled.

The relation between a Public Port and its Plant.

We have said that the plant of public ports was either nil or very elementary; also that it rarely was of a suitably public character.

Let us consider the consequences of this defective state of things and seek its remedy.

Is it necessary, *a priori*, to equip *all* ports?

In what should the equipment of any given spot consist? And by whom should the cost be borne?

Such are in our opinion the principal questions to be examined.

The ports of the French navigable waterways present extremely diversified characters, both in their normal use and working and in their individual importance. None of them are capable of being worked as are the maritime ports, or especially as the large navigable rivers of Germany and Holland. None are required to have a plant to be compared to that possessed by these last named ports, which are really district ports. These ports are frequented by large craft like sea-going vessels. Their daily expenses are considerable and quick loading and unloading is with them a matter of importance. Merchandise for distribution over a large area flows into these ports under conditions similar to those of a seaport. As in a maritime port they are put in the warehouses before being forwarded to the various places of consumption and often are sold only after their arrival.

The French inland waterway ports have generally nothing of this character. They are essentially ports for local traffic and consumption. Only some few ports lying near the head of the main waterway have anything of the nature of transit or transhipment ports.

The working of our inland ports in France cannot therefore be compared to that of maritime and large river-ports. Neither can, except in rare cases, the same or similar plant be appropriate. A much smaller plant will ordinarily suffice, but it should in all cases be specially suited to the productions of the district, or to the materials brought to it from a distance for its consumption.

The plant most suitable will vary greatly in different ports. It is clear that the simple widening and resulting mooring-width of waterway suitable for a village will not suffice for a town of considerable population, nor will the necessary gear and apparatus be identical in the two cases. Again there can be little analogy between the appliances needed for a port of an agricultural district, an industrial centre and a quarry from which building stone is got and dispatched.

In small canal and river ports, such as our inland ports mostly are, plant suitable for maritime and large river ports must not be introduced. But however small they may be, canal and river ports ought not to be neglected; it is possible to improve them. It is imperative that their plant should be complete; but extreme prudence should be exercised in effecting this.

Classification of Ports according to their Requirements.

The precise necessities of a port must first of all be specially studied. These necessities depend mainly on the nature and the amount of traffic.

To arrive at something like correct conclusions we have divided ordinary public canal and river ports into three classes:

1. Secondary or subordinate ports, comprising all widenings of waterway for the service of hamlets, villages and small towns possessing little commerce or industry.
2. Ports in large commercial and industrial centres and ports of large towns.
3. Transit or transhipment ports.

We will say a few words on each of these three cathegories of ports taken separately.

Secondary or Subordinate Ports.

The traffic of these ports is generally very small and no hopes can be entertained of its increasing. What small amount of merchandise does arrive or is sent off interests most frequently but a very limited number of traders, and the variety of material is not great. Apart from such heavy material as building stone, rough timber and large metal pieces which, without powerful appliances it would be impossible to load on the waterway, no special appliances are necessary. (The powerful appliances here referred to will be treated of in a subsequent paragraph). It may be asked whether in ports of this class with such limited traffic hand labour may not be most economical. So many different considerations and circumstances may have weight here that it is imposible to come to a general conclusion. Admitting that at certain points one or two cranes might render useful service, the number of traders interested is too limited to support the ontlay requisite for providing them. The intervention and help of public corporations either directly or by trustees appointed by them might be both inconvenient and dangerous. For instance in a small port the giving up of business or the removal of a single manufacturer might throw idle and useless an apparatus provided at heavy cost. Again an excessive development of plant under pressure of public opinion is at times also to be feared; the redemption of the debt and even the interest on the capital expended might not be always assured.

In short, all things considered, private enterprise seems to be the only means which in the cases in question guarantee against errors of valuation and abuse and should continue to be the natural regulator of outlay.

Is it suggested that the public corporations should take no part in the arrangements? By no means. Private initiative should be encouraged and facilitated. To this end the formalities to be fulfilled should, by the cares and endeavours of administrative public corporations, be made as easy as possible. Without excluding any of the formalities essential for the security and freedom of navigation and the full use of the lands pertaining to the waterway, and to give if necessary a public character to the apparatus, a wise and prudent decentralisation of power of granting authorisations may be studied and may be considered useful and desirable.

Private enterprise we repeat should be left to do the rest.

Ports in large Commercial Centres.

Immediately a port acquires or gives promise of acquiring a certain importance, the conditions are changed. The necessities and requirements of such a port are varied. There is loading and unloading of different goods for widely separate places; sometimes these goods are warehoused in the ports; or again, out-going or in-coming merchandise may require that the merchant or manufacturer should at once divide and repack them, protect them from the weather, or in all or part store them for a certain time awaiting contingencies.

To ensure the port's prosperity, suitable cargo handling appliances must be provided for loading and unloading, either directly or by using the ground spaces, the various kinds of material composing the cargo; also sheds, warehouses, docks and yards arranged and fitted, as in works and factories, in such a way as to avoid unnecessary intermediate handling of goods in their transference from ship to warehouse or the reverse.

There should be connecting lines between waterway and the railway systems for facilitaling the direct or indirect transit, that is to say the waterway warehouses should be in touch at the same time with the railways.

It is indispensable for merchants to know beforehand the exact amount to be paid for each service rendered.

There is thus in the equipment of a port of any importance a solidarity of organisation of machinery, warehouses, docks, railways etc. Moreover once the working plant is acquired, there is the working management or staff to be attended to and organised.

It is evident that the problem we are studying cannot be resolved as a whole and as defined in its generality, but we may approach the solution as nearly as possible and apply the principles of it as far as they are compatible with the traffic of each port.

Now, whatever the equipment required, let us ask who is to provide it.

The persons using the port are numerous; they change and continually increase or decrease in number. A direct general understanding amongst them is difficult, if not impossible. Only large contractors may sometimes undertake as a whole complex work of this importance. In this case the too often excessive profits of middlemen weigh upon the commerce and the navigable way. Should therefore private enterprise and initiative be excluded? Assurely not; but the intervention of public powers (i. e. powers such as Chambers of Commerce or Navigation for example) may then exercise a useful discretion when necessary in removing obstacles and suppressing the abuses which might result from thom.

Concessions for laying dwon plant should moreover be subject to such restrictions and guarantees as will effectively secure their working to the best interests of the general public they are intended to serve. These concessions must emanate from the central power.

Power for handling heavy material.

In a previous paragraph we promised to speak specially of appliances for the manipulation of certain heavy material. The materials referred to may be met with at all ports, whether such ports be otherwise of importance or not, even in ports in remote country districts. Emanating from quarries, forests and other similar sources the heavy materials may be intended for different points along the navigable waterway. The appliances necessary for handling them are otherwise little profitable, but lack of these may impede the working of the natural wealth and products of a whole district. Private enterprise will rarely dare to risk the outlay necessary for providing the powerful apparatus in question; rarely too would private endeavour solve the problem of its supply in the most rational and economical manner, namely by transportable appliances capable of being taken from port to port along the waterway to effect loading and unloading operations, neither in private hands would it ordinarily be possible to arrange the work to be done by these machines at widely varying distances.

It therefore seems that apart from the importance of ports, the public powers and corporations should intervene for the establishment and provision of these powerful appliances to be used along a navigable way or a system of navigable ways.

Transhipment Ports.

In speaking of the ports in important commercial or industrial centres, we have already had occasion to speak of transhipment ports and have said that these should as for as possible be in direct connection with the railway systems to and from the ports' own docks and warehouses.

It is desirable too that the communications between the railways and canals should be numerous and, as far as local circumstances allow, that points of convergence of railway traffic should be established, where the railway may become a feeder to the waterway and distribute its merchandise over a large area.

The question was discussed at Manchester and at Paris and the conclusions arrived at merit support.

With regard to the arrangement and plant in these ports, in addition to the general conditions already laid down and applicable to transhipment ports as well as others, we can only insist on the following principal points.

The object of plant in ports is to facilitate and to lesson the cost of handling goods; it should be so stationed that the latter can be transferred directly from water to rail and vice-versa. and at the same time so that the quay-space may be left clear for storage sheds.

When the extent of the ports permits, part of the plant may be specially placed for direct loading between rail and water, and the other part placed where best suited for depositing goods in warehouses. Where the port is deficient in length, there may be reserved between the quay-wall and the quay service transhipment rail a sufficiently wide space for sheds; on this quay-space there may be placed cranes of sufficient reach to allow of direct loading or unloading.

An advantageous arrangement of the transhipment line seems to be that of giving it a height which will bring the floor of trucks on a level with the raised quay-space on which the sheds are built.

Under any circumstances there ought to be one or more supplementary lines of rail contiguous to the main transhipment line, and at least one as a siding for empty waggons; also it is important, if transhipments are made in both directions and there be but one transhipment line, that this line should be connected with the shunting stations in several places, at least at the two ends, by either points, turn tables or revolving side-rests.

Merchants should handle their own merchandise with the public plant and not leave it to companies whose station charges are at all times onerous. It is equally desirable that the railway connection arrangements be such as to avoid excessive charges for goods passing over but a short distance of the main line.

In the description of the working appliances of the Marne au Rhin Canal to follow several transhipment ports will be noticed, two of which, though not advantageously situated, show a large traffic.

CHAPTER II.

Plant of Ports in Coal and Manufacturing Centres.

A. COAL PORTS IN THE DEPARTMENTS OF LE NORD AND LE PAS DE CALAIS.

Total output of coal and quantity sent away by water.

Of the total yield of all the pits in Le Nord and Le Pas de Calais taken together nearly one third is sent away by water. The 12,430,000 tons of coal raised in 1889 increased to 14,500,000 tons in 1892. The quantity despatched by water was in 1889 4,100,000; and in 1892 more than 4,400,000 tons.

All the coal companies have been preoccupied as to the best arrangements and appliances for loading and forwarding coal by water.

All the large companies now possess one or more ports specially fitted with the most suitable plant for the purpose; the 17 pits belonging to the Anzin Company are in connection with 4 different ports.

The following table gives for 1892 the total output and the quantity of coal sent away by water from each of the large companies.

Company.	PORT.		Output 1892.	Sent away by water 1892.
	Pas de Calais coal Dock.		Tons.	Tons.
Dourges	Noyelles Gedault,	Water station at the junction of a branch which communicates with the Deule .	616,000	154,000
	Courcelles	Wharf on the upper Deule		43,000
Courrières	Harnes	Wharf on the Lens canal	1,398,000	647,000
Lens & Douvrin . .	Vendin	Water station and Wharf on the upper Deule	2,102,000	693,000
Bethune (Bully Grinai)	Violaines	Water station on the Aire canal . . .	1,118,000	420,000
Noeux	Beuvry	Water station at Beuvry branch extremity, Aire canal	1,038,000	437,000
Bruay	Bethune	Water station on the Aire Canal . . .	918,000	395,000
Marles	Annerin (Bethune)	do.	695,000	249,000
Ferfax	Isbergues	do.	223,000	49,000
Lievin	Eleu	Water station at Lens Canal extremity	700,000	169,000
Meurchin	Meurchin	Water station and wharf on the upper Deule	278,000	71,000
Carvin	Courrières	Wharf on the Succhez-Lens Canal. . .	203,000	24,000
Drocourt	Pont à Vendin	Public Wharf on the upper Deule Canal.	296,000	53,000
Various Companies .	. . . .		250,000	41,000
		Total for the Pas de Calais dock	9,835,000	3,445,000

Company.	PORT.		Output 1892.	Sent away by water 1892.
			Tons.	Tons.
		Total for the Pas de Calais dock.	9,835,000	3,445,000
	Le Nord Dock.			
	Vieux Condé	Wharf on the lower Scheldt.		155,000
	Thiers	Wharf on the middle Scheldt		40,000
Anzin		Wharf of l'Enclos on the middle Scheldt	2,718,000	416,000
	Donain	Station of the factory branch of Denain (middle Scheldt)	798,000	129,000
Aniche	Gayant	Wharf on the middle Scarpe.	432,000	84,000
Escarpelle	Dorignies	Wharf on the upper Deule	328,000	91,000
Douchy.	Lourches	Wharf on the middle Scheldt	105,000	15,000
Vicoigne	S^{t} Amand	Wharf on the lower Scarpe		
	Thivenelle	Wharf on the Mons-Condé canal . . .		9,000
Fresnes-Midi . . .	Fresnes	Wharf on the Escaupon branch (middle Scheldt)	132,000	34,000
Various Companies .	. . . .	. . . .	150,000	
		Total for Le Nord dock	4,663,000	973,000
	The Totals for the Pas de Calais and Le Nord dock taken together		14,498,000	4,418,000

BRIEF DESCRIPTION OF SHIPPING PORTS.

(See Plate I.)

Most ports of importance have a station which is connected with the river or canal. Along the lower Scarpe, the Scheldt and various canals of Le Nord the wharfs are often on the bank of the waterway. Confining ourselves to those showing more than 40,000 tons annual tonnage we mention the following.

The Harnes wharf (Courrières Company) on the Souchez (1) (Lens) Canal; the Dorignies wharf (Scarpelle Company) on the upper Deule Canal; the Guayani (Aniche Company) on the middle Scarpe; the Vieux Condé (the Anzin Company) on the right bank of the lower Scheldt; and the Lourches wharf (Douchy Company) on the left bank of the middle Scheldt.

The Drocourt coal mining company embarks its coal at the public wharfs of Pont à Vendin.

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(1) It is to be noticed that the Harnes port was formerly in connection with a 3 kilometre private channel of the Courrières Company. That waterway called the Souchez Canal was afterwards, in 1889, prolonged under the name of Lens Canal beyond the Eleu port (wharfs of the Liévin mines).

For its wharfs at Fresnes the Fresnes-Midi mining company is utilising the unused Escaupont branch.

The Eleu wharf (Liévin mines) corresponds with the extreme end of the Lens canal (a prolongation of the Souchez canal).

The Noyelles-Godault (Dourges mines) and Beuvry (Noeux mines) ports have each a station at the end of a private branch of waterway; these branches are 440 and 2,600 metres long respectively.

With regard to stations properly so called, as circumstances require, they are either parallel, oblique or at right angles to the canal or navigable waterway.

The Vendin station (Lens mines) and the Violaines station (Bethune mines, a concession of Bully Grenay) are parallel or nearly parallel to the canal.

The two stations of Béthune and of Annezin (Bruay and Marles mines) are at an angle of 35° to the canal (1).

And finally the Meurchin (Meurchin Company) and Isberges (serving the Ferfay and the Auchy au Bois and Fléchinelle mines) stations are perpendicular to the canal.

Also the three stations at Denain for the workshops etc., are perpendicular to the old Scheldt; two of these three are used almost exclusively by the Anzin coal companies.

Ports on one of the banks of the navigable waterway.

In front of the Harnes wharf the canal is from 15 to 23 metres wide, whilst below the normal width is only 8 metres. Also, up-stream the Lens forming a prolongation of the Souchez canal is but 11 metres wide. The Courrières company use the right bank only; the left bank, on which is the tow-path, is left free for the passage of boats. The wharfage has a length of 840 metres; it has a quay-wall 400 metres long rising 3 metres above the water-level, on which stand two loading appliances; there is a length of 150 metres wooden staging carrying 3 cranes for loading big coal, and lastly an incline (2 in 3) for pit props on the right.

The upper Deule and the middle Scarpe have a normal width of 10 metres at the water-level. To the right hand of the main wharf of the Escarpelle Company at Dorignies, since the opening of a public wharf by the State, there is a total width of 22 metres. To the right again of the Gayant wharf the Scarpe is 16 metres wide on the surface of the water; this enlargement of width and mooring space was effected in 1882 at the cost of the State, because a swing-bridge at this point often necessitated the lying to and waiting of boats. The width is 19 metres along the quay constructed by the company for the shipping of its coal.

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(1) To be exact we must also mention the unimportant basin constructed by the Escarpelle Company and by them used concurrently with the two wharves on the Deule.

The public port of Pont à Vendin corresponds to a widened length of waterway in the Deule Canal (17 m. wide) of 300 metres.

The Drocourt company generally occupies only sufficient length for one boat.

Water stations properly so called.

To the right of Eleu, the Liévin Company has formed a station 22.50 m. wide and 268 m. long, with brick quay-walls, and at its entance a smaller side station to allow of boats passing. The quay-walls are 1 m. above water-level, except to the right of the loading gear where for a distance of 118.50 m. the height is 5.20 m.

The Dourges station is 100 m. long and 122 m. wide. Its wharfs on the two sides are 3 m. above water-level. The company has put up three loading hoppers. Above and below the mouth of the branch (440 m.) which serves the station, the Upper Deule canal has a normal width of only 10 metres, but it is intended to increase the width to 16 metres over a distance of 1 kilometre, so as to accomodate empty or loaded craft; this is to be done by the State and the Dourges Company conjointly.

The Beuvry station, at the extremity of the branch bearing the same name (constructed as well as the station proper by the Nœux Mining Company) consits of a basin 220 m. long and 18 m. wide, with a small side basin at the entrance for convenience in passing; on one side there is a wharf 150 metres long with two loading hoppers, and opposite this the quay 200 m. long is used especially for loading briquettes. The wharfage is prolonged 320 m. beyond the length of the basin for the storing of coal and pit props (manipulated by hand).

The Vendin port (Lens mines) had originally a width of 18 m.; in 1890 this was increased to 32 m.

At the same time the Lens mining company gave a length of 360 m. to the basin in which is the small side basin. On one side of the basin is a quay-wall of 275 m. long with 47 shoots; the height above water-level is 5.85 m.; on the opposite side the wharf is only 1.50 m. high and is used for loading large coal and to some extent also for unloading props. Near the basin the width of the Deule for a length of 1800 m. is now 16 m. The company contributed towards the amount spent on its widening. The improvement was urgently needed not only as a mooring space for boats awaiting their turn, but also because the Lens Company uses the bank for loading and unloading. Coke ovens are also erected along the bank.

The Port at Violaines (Bethune Mining Company) consists of a 320 m. station 22.50 m. wide, with a supplementary side basin at its point of connection with the canal. One side of the main basin has a wharf (8.80 m.

above the water's surface) with two loading hoppers. The other side is used for discharging props and for loading coke from the ovens, in which the company's coal is burnt.

The Bruay Company's port, in the Béthune township has a basin 350 m. by 25 m·, with wharfage on each side 2.50 and 3.00 m. above water-level; 4 coal-tips with corresponding hoppers are used for loading.

An outer harbour 240 m. long by 12 m. wide, extends between the basin proper and the subsidiary one at the junction with the canal. The slope of the bank serves for discharging pit props.

The port at Annezin (near Béthune), belonging to the Marles Mining Company, is 337 m. long 22.50 m. wide, and has beside the large basin also a supplementary siding water at the junction with canal. Along one side of the former is a quay-wall 6.10 m. above water-level, forming a warf on which are two coal-tips with hoppers. On the right of these the quay rises to 8.30 m. The opposite wharf is only 0.60 m. high and is used for landing pit props.

The Meurchin and Isbergues stations belonging to the Meurchin and the Ferfay Companies are of much less importance than those already mentioned. The first (Meurchin) measures 190 m. by 40 m. only. On one side are 6 hoppers similar to those belonging to the Lens Company. Only one boat can be loading at a time. On the opposite wharf, 40 metres long, loading is done by means of baskets.

The Isbergues station, 170 m. long and 22.20 m. wide, with 2.40 m. spring of quay above water-level has two similar parallel wharfs with these measurements.

As to the Denain basins their measurements are 210, 380 and 250 m. long respectively and 22, 42 and 16 m. wide. The two last are used specially by the Anzin Company for loading coal. Their equipment consists exclusively of a mixer, a coal-tip for 10 ton waggons and 3 stationary 5 ton cranes.

PLANT OF PORTS.

Railways.

The various coal companies' wharfs are connected with the pits by railways having the general normal 1.44 m. guage.

In addition to the special line for trucks and waggons which are being loaded, all waterway wharfs are provided with one or two pairs of metals as sidings for empty or for full waggons, or as subsidiary lines for the service of the stacking space for coal reserves or surplus, or again as shunting and sorting lines. Thanks to these last, waggons may be forwarded from the colliery in any order and without attention to the special making up of trains according to size and quality of coal. The sorting of the waggons to suit the shipments to be made will be done at the port.

The arrangement and organisation of the system of lines generally will vary greatly in different ports; it is impossible to formulate a general rule as an examination of the annexed plans will make evident. (See Plate I for the various systems adopted by different companies.)

Also the quantity of produce it is possible to load directly or to store will depend greatly on the space the companies can dispose of at their wharfs. At Denain, Harnes, Beuvry, Béthune (Bruay) there is large supplementary stacking and storage space. The Bruay companies in particular have put up roof shelter for 20,000 tons.

The system of lines and sidings is generally arranged on one and the same level. At Violaines (Béthune mines) and at Annezin (Marles mines) a gradient allows of the sorting and classing of trucks at the least possible cost. The line serving the hoppers has equally in some cases a slight gradient permitting of easy working.

At the Béthune wharf a gradient of 8 in 1000 near the loading tackle falls away to 3 jn 1000 at the far end of the sidings. At Violaines the gradient is 7 in 1000. Again at the Denain wharf the coal laden trucks are taken to the tippers by means of a gradient of 8 in 100; there is a stationary engine supplying traction power by means of a cable.

On the Annezin wharfs (Marles mines) the rise is 30/10000 from the beginning of the storage and manoeuvring spaces to the first tipper, and increasing to 55/10,000 between itself and the second, the two being 110 m. apart; for the next 410 m. the gradient is 88/10,000. Loaded trucks after having been run to the end of the ways fall by force of the gradient either to the loading points or to the sidings as required.

LOADING AND UNLOADING APPLIANCES.

Colliery owners have been led to seek the most expeditious mechanical means for quick loading of large quantities of coal; in this, expense for hand labour was to be reduced to its lowest and breakage of coal to be avoided.

In a general way this last requirement has restricted the use of machine work to small and mixed or unclassed qualities; for cobble and large coal, baskets and barrows are used.

Cranes.

Loading by cranes is now little in vogue.

The Douchy Company have, it is true, at their Lourches whars 2 steam cranes capable of loading 600 tons in 12 hours; also a fixed $3\frac{1}{2}$ ton and a travelling 5 ton crane.

The Angin company have erected for the service of their Vieux Condé wharf two 3 ton steam cranes.

At Denain the greatest weight of coal is loaded by means of a mixer and a coal-tip which will be referred to later; but there are also three available 5 ton steam cranes each capable of loading 300 tons in 10 hours; these cranes have each a pair of counter-balancing arms of equal length; whilst one arm discharges into the boat one box of from 10 to 15 hectolitre of coal the other arm takes up another load from the quay.

At the Harnes wharf, the Courrières Company have, besides two hoppers, also 3 Chrétien cranes loading 300 tons in 10 hours, for cobble coal. The coal is brought from the pits in 1 ton hinge bottomed tubs on sideless platform waggons; the crane lifts and discharges one tub at a time into the boat.

Loading Hoppers.

The greatest weight of coal is shipped by means of fixed shoots or hoppers of more or less perfect construction, under which the boats are brought into touch with the loaded waggons serving them from the quay metals (1).

On the Isbergues wharf, the Ferfay and Anchy Companies employ spades in discharging 10 ton waggons pushed also by the workmen into touch with the 6 shoots.

On the Gayant wharf the Aniche Company has fixed 2 hoppers at the upper end of a platform 7 m. high; the coal is brought in small 1 ton tubs or waggons, which by the steam crane are lifted to the platform height and emptied into the hopper.

The Ottricourt, Thivencelle and Fresnes-Midi companies have contented themselves with a less elaborate arrangement of raised platforms with hoppers on to which are run 4 ton waggons and by a hand worked lever tipped into the hopper.

LOADING AND UNLOADING APPARATUS ON IMPORTANT WHARFS.

We will examine the arrangements adopted on wharfs fitted out with considerable plant:

1. for quays and shoots;
2. for tipping waggons (2);
3. for shunting waggons and finally for boats.

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(1) In two instances travelling hoppers on platform trucks have been adopted: by the Carvin Company (Courrières wharf) and with the use of spades for discharging 10 ton waggons of normal build; also by the Escarpelle and Courcelle Company who use small 4 ton shunting waggons and a travelling coal-tip on wheels.

(2) We remark that part of the produce from the Anzin Co's mines is loaded in the Denain branch basin by means of a mixer.

Hoppers and coal-tips.

(See Plates II, III, and IV).

Loading shoots may be divided into two classes:

a. fixed hoppers, which may be prolonged by a balanced moveable hopper standing on a raised platform (Lens Company (1), Liévin and Marles Company).

b. fixed hoppers on low quays (Anzin, Courrières, Noeux, Bruay and Dourges Companies).

The systems adopted for tipping may also be divided into two classes:

1. For waggons to carry 10 tons (Anzin Company); the Denain wharf and those belonging to the Thiers, Bruay, Bethune, and Marles Companies;

2. For tipping waggons, the tipping being effected by means of a chain geared either to the shunting engine (see the Lens Company's locomotive steam crane) or to a vertical fixed engine (Liévin, and Courrières Companies) or even to a hand crane (Noeux and Dourges Company).

Handling of Waggons.

The Lens Company have fixed along their special loading quay 47 hoppers coupled together each of which is exactly the width of a waggon, so that one waggon being put in position opposite its hopper the whole train may be tipped without again changing the position.

Elsewhere the number of hoppers and of tipping appliances is limited; there is but one apparatus for transhipments at the Denain-Fosse wharf, and at those of Thiers, Anzin, Eleu (Liévin mines).

The Noeux, Bethube, Courrières and Marles collieries have two on their wharfs at Beuvry, Violaines, Harnes and Annezin.

The Dourges and the Bruay Companies have respectively 3 hoppers and 4 coal-tips. Under these circumstances each waggon must be brought successively to the hopper or the tip.

As we have already seen a certain number of the Companies have given a more or less pronounced gradient to the quay lines of rail; the waggons can easily be moved by hand; this plan has been adopted by the Anzin (Denain wharf) Company, by the Béthune, Bruay, Marles and Dourges collieries. On the Beuvry wharf (Noeux mines) horses are used to move the waggons.

The Liévin and Courrières mines have a small steam engine for the purpose, in the building of which are the tipping appliances for the tipping waggons, the 20 waggons which form each train are attached to two cables winding in opposite directions on the drum of the engine; a gearing lever by this means allows of the train being moved forwards or backwards.

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(1) The Meurchin Company's arrangements are similar to those of the Lens Company.

Handling of Boats.

Thanks to the existence of conveniently arranged hoppers at the Vendin (Lens mines) wharf no difficulty is found in handling the boats; the master and his men manoeuvre them with extreme ease. Where there is but one hopper with which to do the whole of the loading, as often is the case, the question is very different; time is wasted and expenses by the employing of hand labour considerably increased.

To remedy this last inconvenience the Courrières and the Béthune Companies have adopted a system of towing which is almost identical with that of which details are given in the drawing relating to the Béthune mines (See Plate IV).

Along the quay-wall there is connected with a steam-engine an endless chain supported by rollers and pulleys; these latter comprise three loose pulleys on one and the same shaft of which the central one is intended to receive the chain and turns constantly in the same direction; two brass screws on the shaft allow the two side pulleys to be put in motion by simple friction with the central pulley; a cable runs from this arrangement of pulleys, its two loose ends being attached to the stem and the stern of the boat and enabling it to be moved backwards or forwards.

The Marles Company also has a system of manoeuvring its boats by means of an endless steel cable (0.02 m. diameter) on a drum. This cable runs along the quay wall about the height of the boat; to take the boat forwards or backwards a short length of cable running from her must be attached to the end of the quay-cable corresponding to the direction desired. (See Plates II, III, IV).

The detailed drawings of hoppers and of tipping gear and material annexed to this description will complete the brief account of the plant owned and worked by the various colliery companies. The want of space in this paper does not however enable us to give details respecting each company. (1)

We have thought it better to group the matter as we have done, so as to shew the general plan and at the same time the analogous as well as the distinguishing features of each system.

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(1) The official programme of the Vth International Inland Navigation Congress contains a detailed description of the Vendin (Lens mines) Béthune (Bruay mines); and Annezin (near Béthune Muarles mines) wharfs and their equipment. There will also be found in it interesting information as to the Lens Company's hoppers, the fixed hoppers with moveable shoots on raised quays and the tipping gear of Messrs. Fougerat and Jaza-Villain etc., etc.

We will confine ourselves to a brief description of the mixer used on the Denain wharf (Anzin Company) which serves for the direct loading of coal. The apparatus consists of two buckets placed in opposite directions, but by varying the number of these and the working speed different combinations and results may be had. The buckets are fed by hoppers into which the coal brought by waggons is lifted either by hand or mechanically. In the buckets the coal is carried upward and poured into an endless belt or apron and from thence into a 10 ton hopper placed between the mixer and the boat.

Comparison of the Different Systems of Loading Plant.

Each of the several systems has its advantages and its disadvantages.

The coupled hoppers adopted by the Lens company allow of one or several boats being loaded in a very short time. This system also reduces the time spent by loaded waggons on the quay and thus effects an economy on the rolling stock account. The sorting and classing of waggons is simplified if not altogether done away with. On the other hand the first cost of the plant is considerably greater; it must be mentioned that two fixed hoppers properly fitted up suffice for handling 3000 tons a day.

Fixed hoppers with moveable shoots on raised quays, such as exist at the Lens company's quay seem to be superior to the low quay system and have been adopted by all the recently equipped wharfs (Liévin and Marles mines). In our estimation too it is advantageous to give the quay service lines of railway a gradient sufficient to facilitate the shunting and manipulating of empty or full waggons. Also it is well to have a method which should be as simple as possible of manoeuvring the boats.

As to the tipping of coal we fear to pronounce ourselves upon the different systems. In 1885 the Liévin Colliery Company preferred and adopted the hinged body system of waggon and special fixed tipping machinery; the company sacrificed the advantage of mobility of lever apparatus which the use of locomotive cranes as used by the Lens Company necessitates; the tipping machine proper, being thought less suited to their needs, was not adopted. On the other hand the Marles Company adopted in 1889 a tipping arrangement which is found extremely satisfactory; its movement is eased and regulated by the combined action of a differential pendulum and a hydraulic break. We ought also to add that the Anzin Mines Company, who it is true, have but an imperfect plant, purpose giving up their tipping apparatus (see Plate IV) which they find causes a deterioration of the waggons by the return of the cradle; they estimate there is advantage in a fixed cradle and intend to adopt the moveable body but fixed platform system of waggon; they calculate that the time required per waggon discharged can thereby be reduced from 5 to 3 minutes.

Daily Loading power and Time required for loading a *péniche* of 270 to 300 tons on different wharfs.

All the Colliery Companies have apparatus capable of handling a much larger tonnage than is actually met with.

The following table gives, for the largest companies, the loading power per day per machine and for the whole wharf, as well as the time occupied in loading a boat of from 270 to 300 tons (minimum and average time under ordinary conditions).

Companies.	Main Wharf.	Kind and number of Appliances used.	Normal power per 10 hour day.		Time occupied in loading a boat of 270 to 300 tons.		*Observations.*
			per machine.	for the whole wharf.	Minimum	Average.	
			Tons.	Tons.	Hours.	Hours.	
Dourges .	Noyelles	3 hoppers	350	1050	6	9	
Courrières .	Harnes	2 „	1000	2900	2	3	
		3 cranes	300		2	5 (1)	(1) With 2 cranes working at the same time, 6 boats can be loaded simultaneously.
Lens . . .	Vendin	47 hoppers	300	3500	3/4 to 1		
Béthune .	Violaines	2 hoppers	1250	2500	1½	2½	
Nœux . .	Beuvry	2 „	1100	2200 (2)	2	2½ to 3	(2) Not including coal and briquettes loaded by hand.
Bruay . .	Béthune	1 coal-tip	1000 (3)	4000	1 1/2	3	(3) Daily loading power may (according to Mr. FOUGERAT) attain 1500 tons; 200 tons per hour has been reached.
Marles . .	Annezin	2 „	1300	2600	1 1/4	2 1/4	
Liévin . .	Eleu	1 hopper (4)	1250	1250	1 1/4	2 1/2	(4) To increase work later, space for a second hopper has been reserved.
Anzin . .	Denain	1 coal-tip	900	2300 (5)	2	3½	
		1 mixer	500				(5) Not counting 600 tons of briquettes and large coals loaded by hand or by sloping shoot.
		3 cranes	300			10	
	Enclos	1 screen	400	400			
	Thiers mine	1 coal-tip	no information.				
	Vieux Condé	2 cranes					
Aniche . .	Gayant	2 „	„	500		6	
Douchy . .	Lourches	2 „	275	550 (6)		11	(6) Coke, which is loaded by hand, is not included.

Handling of Large Coal, Nuts and Coke.

For large coal machine loading is not generally available on account of the excessive breakage. For this reason the majority of colliery companies have not found it expedient to altogether renounce a less rough method, or to give up hand labour.

We have already seen that the Anzin and the Courrières Companies make use of steam cranes in addition to their hoppers and tipping machinery. These cranes are especially employed for nuts and for coke. Large coal is loaded by hand briquettes down an inclined wooden shoot.

The Lens Company have cranes for the service of their coke ovens. But the Douchy Company, who convert the greater part of their output into coke, employ men, as do also the Noeux Company.

Speaking generally, nuts as well as briquettes are loaded by hand. The time occupied in loading a boat of 300 tons burden may thus be estimated at:

For coke, large coal and nuts	30 hours
„ briquettes	7 „

For discharging by hand (coal, tar, props) a 300 ton boat, 20, 25 and 30 hours is the time generally allowed.

First Cost of Different Plant.

By way of information we think it of interest to know the total cost of equipping a certain number of the ports mentioned in this paper.

The Beuvry wharf loading and unloading plant and apparatus generally (water basin not included) cost the sum of fr. 280,000.

For basin, wharf apparatus and railways the Béthune Company has spent nearly a million of francs.

The Liévin Colliery Company's outlay between 1885 and 1888 amounted to fr. 410,000 for its Eleu wharf.

The plant on the wharf belonging to the Marles Company dating from 1889 cost fr. 1,060,000.

The Staff of the Several Wharfs.

The staff employed varies according to the nature and magnitude of the plant. We may however compare the staff required in different cases for the working of a hopper, a coal-tip or a crane.

On the Harnes wharf (Courrières mines) each of the 2 hoppers employs 6 men, viz. 1 for the hopper itself, 1 for the tipping gear, 1 to manage the waggons, and 3 (the boat-man not included) to distribute the coal in the hold; also 1 man is required for the engine which works the chain by which the boat is towed in either direction. The hands required by cranes (2 or at most 3 are used simultaneously) are: 4 men, of whom 2 are on the crane, 1 hooker for the tubs or bins, 1 man in the boat to open and shut the tubs, also a driver with horse to manage the waggons and 2 shovel-men to stow the coal in the boat; making in all 11 men and 1 horse. There must also be mentioned the wharf-master with his 3 assistants.

On the Vendin wharf, the Lens Company's normal staff consists of the wharf-master and his 3 assistants, 1 engine-driver and 1 stoker on the locomotive crane, 2 couplers and 1 cleaner for the waggons, 4 men to work the hoppers (screens and shoots), and 9 stowers to receive and distribute the coal in the boat.

The staff at the Violaines wharf comprises 9 engine-drivers and labourers for each hopper, of whom 3 are employed for tipping and disposing of the waggons, 1 for the hopper and 5 on the boat; one of these 5 superintends the loading and manages the boat, whilst the other 4 stow the coal.

On the Beuvry wharf, for each hopper there are 8 men and 2 horses. To load by hand in 30 hours 16, 20 and 28 men are employed for coke, large coal or nuts respectively.

The Bruay Company have 10 men per hopper, 2 for the loaded and the empty waggons and 6 for the boat and stowage. Besides these must be mentioned the mechanic in charge of the hydraulic machinery and the wharf-master and his assistants.

On the Annezin wharf the Marles Company's staff is (1 hopper only is generally at work) 11 men, of whom 4 are employed for the hopper (2 for the working and 2 to handle the waggons) and 7 boat-men.

At the Liévin mines' wharf 6 men suffice, of whom 3 are in the boat; the 3 others manage the machinery, hook on and off and work the hopper.

Lastly, if there be taken into account the relative importance of the weight of coal handled at each wharf and the fact that the stowers are chargeable to the boat's account (fr. 0.03) per ton it will be seen that the working expenses do not greatly vary from port to port.

Cost of Loading per Ton.

As to total cost per ton loaded, it is difficult to obtain precise resuls which may be compared. According to the Company's distribution of cost over such or such other constituent elements (stowage, handling and working of waggons between pit and wharf, maintenance of ways, care of machinery, basin and petty expenses, etc.) a considerably different figure will be arrived at. We estimate however that from fr. 0.10 to fr. 0.12 including all expenses, except interest on sinking fund, may be taken as the average.

In a statement issued by Mr. Viola, menaging engineer of the Liévin mines, we find fr. 0.0415 given as the cost per ton loaded; this applies to an annual total of 130,000 tons and is made up as follows:

Manual labour and hauling	fr. 0.0213
Warehouse materials and coal	» 0.0072
Care of plant and sundries	» 0.0130
	fr. 0.0415

Mr. Viola also adds that the expenses would remain almost the same even with an increased tonnage and that fr. 0.032 per ton embarked might be regarded as the average price.

The Marles Mines Company has made similar quotations; their figures are for the year 1893, and for a year's total of 240,000 tons give f 0.0552, as follows:

Management and handling of waggon	fr. 0.0158
Care of plant and various materials consumed	» 0.0078
General expenses, superintendance, etc.	» 0.0316
	fr. 0.0552

It must be added that these results do not include the cost of stowage and arranging of cargo in the boat, which is paid by the owner by his being debited with fr. 0.03 per ton. The cost would be in reality fr. 0.07 or fr. 0.085 per ton.

The Lens Company names fr. 0.06 (of which fr. 0.03 is for distributing and stowing) as the price per ton loaded.

The Dourges Mining Company quote for hand labour alone f 0.068.

The Béthune Company's figure for total expenses per ton is somewhat higher than that of the Liévin and the Marles Companies. It is fr. 0.1249 made up as follows:

Loading proper (labour, including stowage)	fr. 0.040
Petty expenses attendant upon loading coal (superintendence) and weighing of waggons, towage, engine-driver, materials used, extra labour for large coal and nuts	» 0.0094
Maintenance and general expenses, (except interest on capital), maintenance of basin, hauling, care of buildings, staff, manipulating and sorting and shunting waggons on sidings, lighting, coal allowances to workmen, etc.	» 0.0715

The detailed list of items given under the total of fr. 0.0715 seems to justify the divergence between the somewhat large round figure of 0.1249 and the 0.070 and fr. 0.085 given by the Liévin and the Marles Companies. It is probable that these latter have not included in their estimate all the items above mentioned, but have carried them to the pit's general accounts.

We have already given the Marles Mining Companies estimate of cost per ton embarked in 1893 (the basin dates from 1889), fr. 0.0552. Before completing their new wharf the figure was fr. 0.4458. This rate, applicable to the 152,000 tons of 1887 is thus distributed viz.:

For loading into boats by hand	fr. 0.3672
For maintenance of apparatus and for various materials consumed	» 0.0392
General expenses	» 0.0394

The Droucourt Company who have no special plant and who load with barrows at the public wharf of Pont à Vendin pay fr. 0.24 per ton for labour.

B. PORT DE MONTCEAU-LES-MINES.

(Blanzy Mining Company.)

For the purpose of comparing and contrasting it with those put down by the colliery companies of Le Nord and Le Pas de Calais let us now look at the more limited plant at the Montceau-les-Mines wharfs, belonging to the Blanzy Mining Company, whence 400,000 tons of coal are annually sent away by the river waterway.

The characteristic feature of this port is the absolute predominance of hand labour, by which means $^5/_6$ of the total tonnage is manipulated.

The Blanzy Mines' private port at Montceau-les-Mines is situated on the Central canal and consists of a basin 520 m. long and 18 m. wide, lying parallel to the navigable waterway. This basin opens into the canal near a public basin 300 m. long, which serves as a mooring place for empty and loaded boats.

The Company's dock is served by normal-guage service lines put in connection with the Blanzy Railway Co's main system; moreover a multitude of narrow guage lines run in different directions on their ground-space and into their workshops (see Plate VI).

The annexed plan shews the general direction of these lines, whose complex details present no interest from the point of view now occupying us.

Most of the Nord and Pas-de-Calais collieries have the sorting and screening of coal done at the pit head. The Blanzy Company on the contrary have concentrated their apparatus and work near the port; they have there their compressed air machinery, three screens, the briquette making appliances etc. These extend along one bank of their basin, the opposite one is used as stacking ground and storage space for their coal (see plan).

The wharfs are formed by low quay-walls, 0.80 m. above normal water-level.

The plant properly so called of the port comprises:

1. The Railways, normal and narrow guages, above mentioned.
2. The screens, from which the coal is discharged into small waggons holding two hectolitres and from thence runs upon staging to the hoppers and is loaded directly into the boat; or 25 hectolitre waggons are used and directed either to the storage ground or run over a vertical hopper on one of 2 wooden platforms spanning the basin and are by the hopper loaded into a boat; a 40 metre special loading stage on pillars is also used (see G in plan).
3. The above mentioned staging with hoppers by which the 2 hectolitre waggons are discharged by simply tipping.

4. The vertical hopper and the special loading stage also already mentioned.

5. A battery of special gear worked by a transmission-shaft for unloading the tar used in making briquettes; each piece takes up a small tub or waggon, carries it down into the boat's hold (where it is filled by hand) and brings it back to the quay line of railway skirting the basin.

6. A 2 ton crane for loading coke.

All the mechanical appliances, with the exception of the tipping waggons, are somewhat complicated and heavy working.

As already said the greatest part of the coal is not embarked at once from the screen, but stacked and stored on the opposite side of the basin; thence the coal is later taken to the boat in wheel-barrows and loaded. Cranes are used for putting coke on board. Briquettes are passed from hand to hand, or glided down an inclined wooden plane.

In the following table we have grouped, for each of the principal items of port maintenance, the details furnished us with regard to: 1. time occupied in loading or unloading the different types of boat in use on the central canal; 2. hands needed for the work; 3. the cost per ton loaded or unloaded.

GOODS HANDLED.	Tonnage of Boats.	Time Loading or Unloadung.	Staff occupied.	Cost per ton.	*OBSERVATIONS.*
	Tons.				
1. *Unloading :*					
Tar, unloaded by means of waggon lifting appliance above mentioned. . . .	130	1 to 3 days according to staff engaged.	8 to 18 workmen 1 foremen.	fr. 0.77	
2. *Loading :*					
Coal. Loaded by vertical hopper on wharf, or by staging on platform (25 hectolitre waggons)	150	5 hours	6 men	„ 0.07 (1)	(1) The cost counts from the time the coal leaves the screen.
	240	8 „			
Coal. Loaded directly from Screen, by means of the 2 hec. waggons . . .	65	4 »	6 »	„ 0.10 (2)	(2) The cost is low from the almost exclusive use of children for this work.
	150	7 »	14 »		
	240	10 »	14 »		
Coal. Stacked on the storing space and later loaded by w. barrow	65	3 »	12 »	„ 0.25	
	150	7 »			
	240	10 »			
Coke loaded by the crane .	—	—	—	„ 0.75	
Briquettes	—	—	—	„ 0.40 (3)	(3) This cost is an average one class of briquettes causes variation in cost.

Seeing the importance of traffic it might be asked whether there would not accrue to the company an advantage by a reduction of the expense for hand labour incurred by stacking coal and reloading by wheel-barrow, or at least in some measure to improve the loading appliances.

It must be admitted however that the extremely soft and crumbling nature of the coal would scarcely allow of the use of hoppers with a deep fall as used in Le Nord.

B. VARIOUS INDUSTRIAL PORTS.

Port of Marnaval. (Plate VI.)

This port, situated on the Upper Marne canal, at 3 kilometres from St. Dizier, serves tour blast furnaces and one rolling mill belonging to the Champagne Forge Company. This Company at the same time has a concession for the St. Dizier—Vassy canal constructed at its own expense for the service of its mines at Pont Varin near Vassy.

The Marnaval wharf is 560 metres long. It consists of a siding along the up-stream tow-path obtained by a simple widening of the main waterway; its surface width beyond the canal proper is only 2 metres for a distance of 290 m. bordered with quay-walls, and 5 m. for a distance 270 m. with sloping bank. The ground space available is about 20 m. wide and presents an area of a little over one hectare. There is beyond this another half hectare which might be made utilised for storage.

The 1885 port tonnage of 186,131, became 242,430 in 1892, and 243,940 tons in 1893.

The 242,430 tons of 1892 were distributed thus:

Shipped.

	Tons.
Dross	10,718
Pig iron cinder	1,710
Cast, wrought, scrap and various	39,783
	52,206

Discharged.

	Tons.
Iron-ore	117,553
Limestone	46,862
Combustibles	9,909
Cast iron	10,976
Various	4,924
	190,224

The appliances for discharging materials consist of 3 hydraulic cranes for the service of the wharf with quay-wall; these cranes are on the Antwerp model, are travellers on pivots, and lift $1\frac{1}{2}$ tons. Plenty of service lines on the ground space are put in connection with the Eastern Railway.

The permanent way for the use of the cranes runs along the off side of the tow-path at a height of about 1.90 m. A third line allows of waggons being turned into it, and transhipments can by its use be effected when necessary.

Below the surface level of one end of the wharf runs a tunnel with a railway line upon which, through an existing trap, material from the wharf may be landed.

The cost of the 3 cranes including the motive machinery, the accumulator and canalisation was	fr. 80,000
The crane and wharf metals, and the trapped tunnel cost	» 60,000
Altogether . . .	fr. 140,000

The cranes are used almost exclusively for discharging iron ore and limestone; though three are available 2 suffice ordinarily.

Only exceptionally are the cranes used for discharging coal and cast-iron, and still more rarely for coke. Wheel-barrows are generally used for this work. As also when unloading dross, pig-iron and cinder. To load dross on the water stockade platforms with shoots served by tipping waggons are more used.

The time required to discharge a 300 ton boat depends greatly upon the class of material and the staff of men engaged.

With regard to this subject the following table gives interesting details:

MATERIALS.	By hand 6 men.	1 crane with 9 men.	2 cranes each with 6 men.	2 cranes each with 9 men.	OBSERVATIONS
Raw ore.	36 hours	12 hours	8 hours	6 hours	
Washed ore . . .	33 „	10 „	7 „	5 „	
Limestone	48 „	14 „	10 „	7 „	
Coke	60 „	24 „	12 „	—	
Coal	44 „	18 „	—	—	
Pig-iron	28 „	12 „	—	—	

In a 12 hours day, including stoppages and breaks for meals and rest, the following quantities of material can be discharged:

MATERIALS.	By hand 6 men.	1 crane with 6 men.	2 cranes each with 6 men.	1 crane with 9 men.	2 cranes each with 9 men.	3 cranes each with 9 men.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Raw ore . . .	100	200	400	300	600	900
Washed ore . .	100	230	460	320	640	960
Limestone . . .	75	180	330	250	520	750
Coal	75	200	—	—	—	—
Coke	60	150	—	—	—	—
Scrap iron . . .	60	—	—	—	—	—

By working day and night 1650 tons can be handled in 24 hours.

The cost of handling material, per ton loaded or discharged by the different systems of work, including care of appliances and attendant expenses, is as follows:

MATERIALS.	Discharged by Crane.	Discharged by wheelbarrow.	Loaded by wheelbarrow.	Loaded by Hand.
Limestone	fr. 0.20 to 0.22	—	—	—
Raw ore	„ 0.16 „ 0.18	—	—	—
Washed ore	„ 0.15 „ 0.17	—	—	—
Coal	„ 0.24 „ 0.26	fr. 0.40	—	—
Coke	„ 0.30 „ 0.32	„ 0.70	—	—
Pig-iron	—	„ 0.35	fr. 0.20	—
Scrap „	—	fr. 0.50 to 0.60	„ „	—
Dross.	—	—	„ 0.25	—
Moulder's Sand	—	—	„ 0.20	—
Sheet, plates, bars etc.	—	—	„ „	fr. 0.35 to 0.65

On the whole wharf with 3 cranes working by night 1920 tons can be handled in the 24 hours.

This 1920 tons is distributed as follows:

MATERIALS.	By hand Day and Night.	3 cranes by Day.	3 cranes by Night.	Total per 24 hours.
		Tons.	Tons.	Tons.
Ore and limestone	—	850	800	1650
Coke	60	„	„	60
Coal	75	„	„	75
Pig-iron	75	„	„	75
Scrap „	60	„	„	60
			Total	1920

A large part of the ore discharged at Marnaval comes from the Company's mines at Vassy. The ore is put on the Vassy—St. Dizier canal at the Pont-Varin wharf by means of a platform with hoppers fed directly from the quarries by an inclined way, small waggons and a coal-tip of very simple construction being the appliances used for this loading operation. (For sketch see Plate VI, fig. 4.) Two hoppers allow of from 50 to 60 tons being shipped per hour. The cost of the work is fr. 0.10 per ton, whilst the hand labour still used by some of the neighbouring owners costs fr. 0.30.

Ports of Neuves-Maisons.

(*See Plate VI.*)

The Port of Neuves-Maisons (East Canal, South branch) is an example of a port which is at one and the same time both an important industrial port and a large public transhipment port. It consists of a spacious basin of trapezoïdal shape occupying the site of a former ballast ground and having on one of its sides ample and easy access to the canal.

The transhipment line of railways skirts the quay-wall for 220 m. along the off side of the basin and 550 m. further away runs into connection with the Eastern system (Nancy-Mirecourt branch). It constitutes an independent system, conceded to the proprietors of the iron works, who use it at the same time and especially for their yards and works.

For public transhipments no plant exists; nevertheless between the quay at the point of junction with the main line there is a narrow guage way, belonging to the iron works, on which cranes might be placed. But the transhipments are limited to:

Goods shipped	2026 tons
» discharged	1002 »
Total	3028 tons

The smallness of this total is attributable to the conditions and charges involved by the legal situation as to the junction point of the two systems (the neighbouring company have exclusive rights, obtained by concession, the junction being looked upon as a common station).

The accumulated costs of transhipment are the following:

1. *For goods brought by rail for the waterway:*

a. Station charges on arrival at the transhipment junction (equal division between the two companies (i. e. the Eastern and the Concessionaires)	fr. 0.40
b. Station charges on arrival in port	» 0.20
c. Cost of unloading from waggons	» 0.30
d. » » loading boats	» 0.30
Total	fr. 1.20

2. *For goods arriving by water to be forwarded by rail:*

The charges are identical, though made in inverse order.

Under such conditions a transhipment port becomes useless.

The port is equally a local public port, here without interest.

As an industrial port Neuves-Maisons is important on account of its traffic and cargo handling appliances.

The proprietors of the Neuves-Maisons works also own the mines from which the ore sold is conveyed to the port by a private railway. This railway terminates at a construction shewn at point A of Plate VI, consisting of a shaft or shoot of masonry with floor inclined towards the canal, a metal funnel or hopper with a mechanical arrangement at its upper end for raising it forms a continuation and receiver. The shaft is capable of containing 50 tons of ore, and the waggons are emptied into it as they arrive from the pits. Between the metal funnel and the shaft is a moveable door which is opened when a boat is to be loaded. The lower end of the funnel is also moveable and thus allows of a better and easier distribution of the ship's cargo.

This apparatus cost fr. 15000.

By it 200 tons can be shipped in 5 hours.

Including interest on the capital the cost of handling is fr. 0.07 per ton.

Done by hand labour with wheelbarrows and temporary plank runs it is estimated that the cost would be f 0.20 per ton and that from 20 to 22 hours would be required for the work.

Annually 70000 tons of ore are shipped by this apparatus.

On the same side of the port as the works there are 2 hydraulic cranes of $1^1/_2$ ton power; both are stationary.

They are used for discharging coke which they lift in tubs or small waggons upon a platform and thence are tipped into adjoining shoots with hoppers; from under these the coke is taken as required to the furnaces.

Working together the 2 cranes can discharge 200 tons of coke in 20 hours at a cost of fr. 0.375 per ton including interest on the outlay.

By hand with baskets the same work would require from 48 to 60 hours and would cost from fr. 60 to fr. 80.

The cranes manipulate 36000 tons of combustible material annually; their first cost, not including pipes, was fr. 28000.

Near these last is another hydraulic crane for coke that is to be stacked in the open; this is also moveable; its lifting power is 2 tons. It is moved by hand. Its working power is 200 tons in 24 hours. Including interest on outlay fr. 0.275 per ton is the working cost for the 24000 tons of coke discharged annually by this crane. Crane and line of road cost about fr. 24000.

Port of Bas Vignon.

(*See Plate VI*).

The port of Bas Vignon, on the Seine, constructed exclusively for the service of the Essone Paper Mills, and of which we annex a plan, was described in the official programme of the Paris Congress. It consists of a 110 metres length of quay-wall along the wharf, and has a height of 4.40 m. above the normal water-level of the Seine. Behind this line of quay-wall is a railway carrying 3 cranes to lift $1^1/_2$ tons each.

Locomotives run the waggons on another permanent way parallel to but behind the line used for the cranes.

An 18 kilometre length of railway connects the port with the Essone Paper Mills and their annexes and with a railway station.

Of the cranes, each with its bins cost fr. 14,500.

The cost of the port was fr. 120,000.

Each crane is capable of unloading 300 tons in 11 hours; its staff of workenen whilst operating numbers 11, viz. 8 in the boat to fill the bins, 1 on the wharf and 2 for the crane.

Of billet-wood and wood pulp 180 to 200 tons per day can be discharged.

The cost of unloading is estimated to be per ton:

For coal	fr. 0.50 per ton.
Wood Pulp	" 0.90 " "
Wood in billets . . .	" 1.20 " "

The annual traffic of the port is 136,000 tons consisting almost exclusively of dischargements: viz. of coal 56,000 tons, wood pulp 37,000 tons, wood (in billets) 23,000, china clay, sulphur, resin, sand and gravel 20,000 tons.

Port of the Soda Works at Chauny.

This port is formed by the Oise, in which river the water by means of a dam has been given a depth of 2 metres over a distance of eight kilometres. In what may strictly be called the port the width is from 18 to 20 metres; higher up stream it does not exceed 15 metres.

By means of a lock the port communicates with the St. Quentin canal and a point above the Chauny lock.

The wharf of the soda works is on the left bank of the Oise, it is 240 metres long, and is served by 1100 m. of normal guage railway by which it is in connection with the Nord Company's system. The ground space belonging to the wharf has a total area of 4500 sq. metres and is occupied mainly by the service lines of rail, leaving no available space for storage.

Five hundred metres above the above mentioned lock is a supplementary port on the right bank of the Oise. Here is a quay used exclusively for the material brought in boats for four furnaces. This quay is provided with neither rails nor cranes.

The port was established in 1865; it would be difficult to estimate its first cost as important changes have repeatedly been made.

The apparatus may be described as follows, viz.:

1. For unloading raw material there are two 2 ton steam cranes; and for reloading also 2 cranes of older pattern and somewhat less power.

2. For bulk cargoes of manufactured products (burnt pyrites, sulphates, hyperphosphates) tipping waggons are used, for the service of which shoots have been constructed.

Packed goods are loaded by hand, rollers or ordinary cranes.

Incoming or outgoing merchandise and products generally are never allowed to remain on the quay; they pass directly from the boat to the Soudière company's waggons, or inversely from waggon to boat.

The work is done by a staff of quay labourers; of whom, for each apparatus working, there are 6 or 8 men in the boat, 1 driver on the crane, and 1 man for emptying the bins on the waggon; in this way in 11 hours there can be discharged:

from 350 to 400 tons of pyrites;

„ 280 to 300 tons of phosphates, salts or coal, or about a boat load.

For loading manufactured goods by hand the staff varies, but on an average consists of 6 men per boat.

The time occupied also varies and is difficult to fix, as it is largely dependent upon the rapidity with which the goods are delivered on the wharf; as a rule the boat is 2 or 3 days in loading its 250 or 270 tons.

The quay staff consists of:

For unloading, 20 men, including crane men and tippers.

For loading, up to 15 men, but the number fluctuates.

At the supplementary port above mentioned, during 5 months of the year 24 men are engaged discharging and stacking chalk.

In their estimate of the working cost per ton loaded the proprietors of the ironworks have included certain interior expenses. Deducting these for loading and unloading the approximate cost may be calculated to be:

For Arrivals. From ship's hold to waggon:

Coal	fr. 0.40 per ton.
Salts	„ 0.35 „ „
Phosphates and pyrites .	„ 0.23 „ „

For Goods shipped. From waggon to boat's hold.

Hyperphosphates	fr. 0.25 per ton
Sulphate of Soda and residuum of pyrites	„ 0.18 „ „

The total figure of arrivals and departures given for the ports of Soudière and Chauny were for 1893 about 200,000 tons, made up as follows.

Arrivals:	Coal	45 000 tons.	146 000 tons.
	Salts	26 000 „	
	Phosphates and pyrites . .	61 000 „	
	Various	14 000 „	
Goods dispatched:	Hyperphosphates	20 000 Tons.	52 000 „
	Sulphate of soda and res. pyrites	31 000 „	
	Various	1 000 „	
	Total . . .		198 000 tons.

CHAPTER III.

Plant of Ports on the Marne au Rhin Canal.

General considerations.

From Vitry-le-François to Xures on the German frontier the Marne au Rhin Canal has a length of 210 km.

The united total traffic of its ports may be roundly put down at 1,750,000 tons yearly, viz:

Shipped	750,000 tons
Discharged	1,000,000 »
Total . . .	1,750,000 tons

The exact tonnage for 1891, 1892 and 1893 was as follows:

	SHIPPED.	DISCHARGED.	TOTAL.
Year 1891	745,132 tons	1,042,309 tons	1,787,441 tons.
» 1892	744,300 »	971,830 »	1.716,130 »
» 1893	767,702 »	997.559 »	1,765,261 »

All loading and unloading is effected either at public ports and wharfs, or on wharfs belonging to industrial or commercial establishments, in mooring sidings and docks or in sections of the ordinary waterway.

The total length of available wharf in public ports is 8694 metres.

Outside public ports the total length of bank used for effecting loading and unloading operations is approximately 8238 m.

The above total tonnage of 1,765,261 being divided by the sum of the two lengths just given (i. e. the 16,932 m., over which the tonnage is distributed) thus: $\frac{1,765,261}{16,932}$ gives 103 tons as the weight of merchandise shipped or discharged per lineal metre of wharf and other loading siding.

Of the total 16,932 metres a length of 6590 has vertical quay-walls; the remainder has a simple sloping bank; this slope is usually 2 in 3 and is in some cases faced with stone, but only for the most part as far as the water-level.

It will be easily understood that the average 103 tons per metre is very inconstant at different points of the canal.

It varies from nothing in certain little frequented ports, or divisions of ports, to thousands of tons in ports of important traffic.

Public plant of the character already described is very insignificant on the Marne au Rhin Canal. In some cases where cranes have been authorised, the condition of public hire at a maximum rate has been imposed; little advantage however is taken of this by the public in whose interest the privilege was exacted and the appliances are used but by the manufacturers or forwarding agents who provided them. For none of the apparatus has a formal equalisation of the table of tariffs been carried out. The application of the clause spoken of is therefore in no way controlled by a board for the administration; it is inserted in the authorisation rather to assert the temporary character of the latter and, in case of public necessity, the right of immediate withdrawal by the board.

But if public plant is wanting there exist along the canal private appliances which, without being numerous, yet serve a considerable portion of the general traffic of the various ports.

Below we tabulate this traffic for the whole length of canal and give certain information as to ports which are provided with either a full complement of apparatus or at least some special cargo handling appliances.

In all ports not specially mentioned hand labour aided by rollers, baskets or wheelbarrows according to the nature of the material handled is in use.

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric positions.	Length of Bank for Loading and Unloading.		Goods		Total Traffic.		Tonnage handled by [illegible]	OBSERVATIONS.
			without quay wall.	with quay wall.	Shipped.	Discharged.	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Public port of St. Etienne	70	3.5	120		228	1.197	1.425	—	—	
Public port of Plichancourt	69	6.	120		681	97	778			
Tournay farms and public port of Brusson	69	7.5	120	—	5.273	4.074	9.347	—	—	(A)
Public ports of Bignicourt and Etrepy	68 67 66	from 10 to 16.5	320*		4.527	1.322	2.402	3.447	—	B * 81 m. in open canal.
Public port of Pargny and tile works	64	19.	380*	—	11,891	4,541	16,379	53		C * of this 40
Public port of Sermaize	60	24.5	310		25,132	16,618	36,130	5,620	11,000	D * The 100 m.
Sand pits, sugar Refineries		25.5	100*	—						

(A.) — The Tournay farms of 500 hectares have connection with the port of Brusson 3 km. away by a Decauville line of railway. Shipments are made and deliveries taken at this port to the extent of 4890 and 3947 tons respectively, or together 8864 of the total of 9347 tons at this port. Brusson affords an exemple of a public port largely devoted to private use and without plant.

(B.) — Of the total 5849 tons here indicated, 3023 are shipped and 424 landed by special permission in open stretches of the canal.

(C.) — 10531 tons are shipped and 3885 discharged (together 14416 tons of the total 16379 tons of traffic), by two tile works respectively 3 and 1.5 kilometres distant 53 tons were loaded in open canal.

(D.) — As to the total traffic here given, we note the following details:

1. Shipped in open stretches (special authorisation):

From two sand pits 1500 m. from the canal	5,161 „
Various	459 „
Total	5,620 tons.
Leaving for the public port	36,130 „

2. Of this same total of 36,130 tons the already mentioned sand pits shew in shipments . . . . 13,084 tons.

A sugar refinery embarks 4865 and discharges 11856 tons; a foundry supplies 2551 tons; making for four firms alone 32,356 tons of the total traffic.

The maximum length of time during which goods may remain on the wharfs of the public ports of the Marne au Rhin canal is 30 days. This is about the only condition imposed. Boats are admitted in their order of arrival and without regard to the nature of cargo &c.

Carried forward	—	—	1,510	—	48,214	27,842	66,939	9,120	11,000

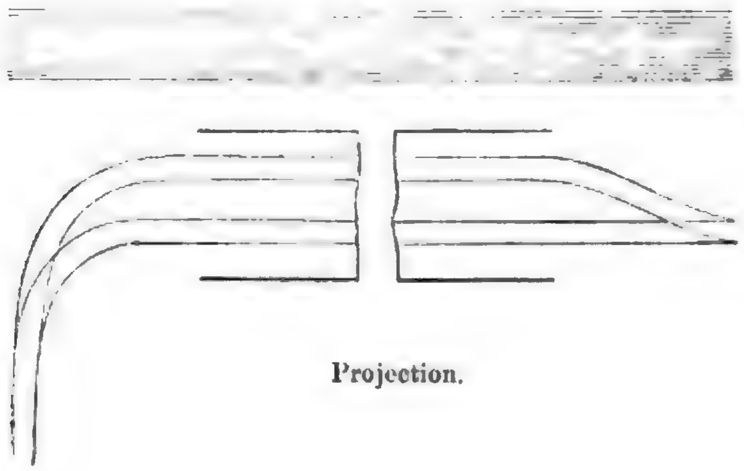
Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	—	—	1,510	—	48,214	27,845	66,939	9,120	11,000	

3. The Sermaize sugar factory from 1878 to 1891 used for unloading at the season of beet-root arrivals — (11000 to 12000 tons annually) — an electric apparatus with a narrow guage connection with the works. The apparatus consisted of a swivelled beam; a travelling platform with dredge like function; a flanged belt similar to a chain with buckets was driven by a Gramme Engine receiving its electricity from a corresponding generator inside the works and 150 metres away. There was about 2 horse-power available.

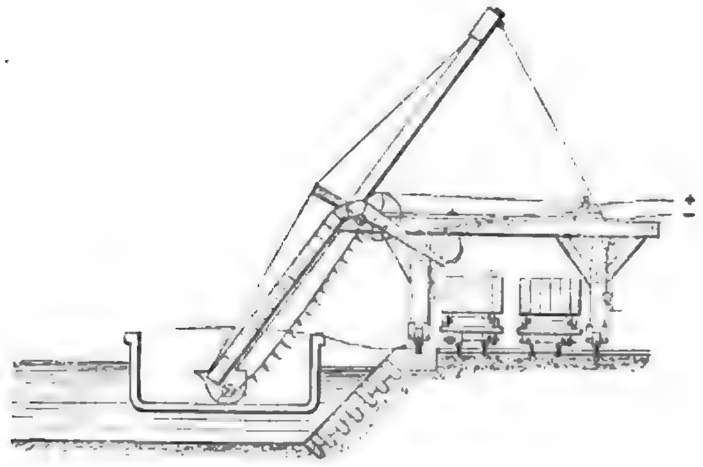
Interest and repairs not included, the cost per ton discharged and carried to the washers 50 metres away was fr. 0.55.

Projecting the adoption of another system of unloading since 1891 the Sermaize sugar factory has replaced the one just described by hand labour. Under these conditions the cost is estimated at fr. 0.75 per ton, and 8 or 10 women or children discharge a boat of 200 tons in 20 hours.

Sermaize Sugar Factory.



Projection.



Elevation of the machine.

Carried forward	—	—	1,510	—	48,214	27,845	66,939	9,120	11,000

Names of Ports and Industrial & Commercial Establishments.	No. of landing.	Reservation position.	Length of Bank for Loading and Unloading		Goods.		Total Traffic.		Tonnage handled by mechanical appliances.	OBSERVATIONS.
			without quay-wall	with quay wall	Shipped	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	—	—	1,580	—	48,211	27,712	66,803	9,120	11,000	
Public Ports of Contrisson and Saulx Works	58	28.7	225	—	9,624	7,556	2,399	14,781	8,500	Saulx Valley manufacturers (E).
Public Port of Braux	56	23.4	100		1,170	156	1,326			
" " " Revigny	52	32	120	—	11,160	961	8,979	3,142	—	Corn warehouses, chinaclay pits (F).
" " " Nouville	49	15.5	120	—	1,341	6	1,347			
" " " Mussey	46	38.5	200	—	5,248	965	6,213	—	—	Timber yard (G).
" " " Varney	45	10	120		1,175	20	1,195			
" " " Fains	43	13.5	120		456	4,076	1,582	2,950		Glass works (H).

(**E.**) — Of the port's total traffic (2399 tons), 1886 tons are shipped by a phosphate works.

The tonnage under the head of private ports is contributed by three ports, viz:

The Hairouville iron-works with 758 tons shipped and 4177 tons discharged;

The port belonging to a phosphates factory with 636 tons shipped;

The port belonging to a syndicate of manufacturers has 6115 tons shipped and 3095 tons discharged.

The Saulx valley manufacturers' private dock is provided with a steam travelling crane on pivot, on a 2.60 m. guage line, with inner rail 1 m. from edge of bank.

This crane is used especially for transhipments between the canal and a connecting line running into the Harouville—Triancourt local railway, constructed by the Meuse Railway company.

The cost of the crane was	fr.	12,000
The way and a site for the crane cost	"	8,000
Making a total cost of	fr.	20,000

The crane's nominal litting power is 5 tons; it is self propelling.

The principal merchandise dealt with are cast iron, coke, coal, ore, sand and stone. A boat of 200 tons can be discharged in 25 hours at a cost per ton of fr. 0.28 including interest on outlay.

Without this crane hand labour must be resorted to with or without wheelbarrows and temporary plank runs. The cost would then be fr. 0.35 per ton, and on an average 35 hours would be occupied in the work.

This crane tranships from 8000 to 9000 tons a year.

(**F.**) — Of the total traffic 8979 tons of the public port, a corn shed contributes 2501 tons in shipments. The 3142 tons traffic in private ports are shipped from the bank from clay pits for brick and tile works.

(**G.**) — Of the port of Mussey's 6213 tons, 2518 are contributed by a timber yard, 1642 in shipments and 876 tons discharged.

(**H.**) — The 2950 tons in private ports are discharged on the bank by a glass works.

Carried forward	—	—	2,605	—	78,385	41,452	89,844	29,993	19,500

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay wall	Shipped	Discharged	Public Ports.	Private Ports.		
			m	m	T.	T.	T.	T.	T.	
Brought forward	—		2,605	—	78,385	41,452	89,841	29,989	19,500	
Bar-le-Duc gas works	40	48.		145	9,234	28,777		3,322	-	Quay-wall built by the works.
Bar blast furnaces	—	—	100	390			-	—	—	* of this 100 m in open canal.
Timber Yard, saw-mill, lime-kiln .	39	47.5	380*	—						
Bar-le-Duc public port. . . .	39	47.5	—	—			28,651	6,036	—	(I)
Public port of Longeville .	35	51.5	120		291	—	291			
Public port of Tannoy	32	54.500			607	57	664	-		
Public port of Trouville . .	28	58.	310		6,488	3,570	2,222	7,836		Lime-kilns. (J)
Public port of Velaines . .	25	60.2	120	—	755	-	756		-	
Public port of Ligny	23	62.5	45	95	1,652	6,890	8,542	—	-	Quay-wall built by the State.
Public port of Geranval . .	20	65.2	120		216	46	262			
Savonnières Quarries and Public port of Menaucourt	18	68.	245	85	16,692	847	10,105	7,434	6,500	Quay-wall built by the Gué Menaucourt Railway Company. (K)

(I.) — The total tonnage of the public port (28651 tons) comprises 421 shipped and 1823 tons discharged, together 2244 tons transhipped to a line running in connection with the local service line of Bar-le-Duc to Vanbecourt of the Meuse Railway Company's system; 2087 tons are shipped and 10,850 tons discharged by the Bar-le-Duc blast furnaces.

Of the traffic of the private ports 88 tons are shipped and 3720 tons discharged by a timber yard; 1771 discharged and 451 shipped in open canal where no wharf or landing place exists.

On the Meuse Railway connecting line there is a pivot-crane of cast and wrought iron on a flat bottomed truck running on the connecting line itself.

The crane cost fr. 6500, lifts 6 tons and is manipulated by hand.

It is little used, probably on account of unfavourable conditions; its total work is limited to a few tons and its data consequently shew nothing.

(J.) — The total of 7836 tons under the head of private ports consists of 6263 tons shipped and 1573 tons discharged in open canal by the Ironville lime-kilns.

(K.) — The traffic given under private ports is contributed by the Gué Menacourt railways junction port; it consits of 5949 tons of building stone from the Savonnières quarries; the stone is put on the boats by means of a travelling platform with a 12.25 m. guage, and of which the rail nearest the canal is laid along the top of the quay-wall.

The cost of this apparatus was	fr. 8000
The connecting line cost	» 2500
Making a total for the whole of . .	fr. 10,500

Carried forward	—	—	4,045	715	114,321	81,626	141,333	54,617	26,000

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of bank for Loading and Unloading		Goods.		Total Traffic.		Tonnage handled by machinery.	OBSERVATIONS
			without quay-wall	with quay-wall	Shipped	Discharged	Public Ports.	Private Ports.		
Brought forward.	—	—	m 4,025	m 715	T. 114,919	T. 81,632	T. 139,914	T. 54,637	T. 26,000	
Public port of Naix	15	70.5	120		392		392		—	(L.)
" " " St. Amand	14	72.5	120	—	70	—	70	—	—	
" " " Treveray	11	75.5	120	—	355	2,022	856	1,521	—	
" " " St. Joire	8	79.5	120	—	2,675	15	2,650	(a) 40	—	(a) Unloaded in open canal.
" " " Demange aux Eaux	2	84.8	120		798	651	1,209	(b) 240	—	(b) Briquettes for public traction service.
Port of Houdelaincourt and Abainville Forge.	[illegible]	—	95	425	8,118	13,414	21,532		14,000	Quay-wall built by State. (M.)
Public port of Mauvages	1	93.5	70	—	2,042	3,662	5,704	—		
" " " Sauvoy	8	98.5	250		1,957	2,044	391	3,610	—	Various private ports (N.), 100 m. in open canal.

The power of the hand-worked appliance is 10 tons.

Without this appliance, so little suited for the transhipment of other goods, it would be almost impossible to handle heavy building stone.

Waggons are sent by the companies to the port on the same conditions as to ordinary stations.

The cost of shipping stone is estimated to be fr. 0.40 per ton.

General goods cost fr. 0.50 per ton, which is little different from the cost of the same work done by hand.

The weight handled yearly by the appliance is between 6000 and 7000 tons.

(**L.**) — By way of memorandum only we mention a port similar to that of Menaucourt; it was made for the use of a quarry and serves for the shipment of about a hundred tons a year of building stone which is taken away by horse traction.

(**M.**) — Of the total 21532 tons named, 1791 tons are shipped and 12982 tons received by boat by a single establishment, the Abainville iron-works.

The port of Houdelaincourt is in connection with the line from Nançois le Petit to Gondrecourt, a line which, from being formerly but of local interest, is now of general interest. Between the connecting line and the quay-wall is laid a 2.60 m. guage way, the inner rail of which is 0.85 m. from the centre line on the quay-wall; this line carries a steam pivot-crane belonging to the Abainville forge proprietors who have the exclusive use of it. Its lifting power is 2 tons; its value, together with that of the road which carries it, is fr. 16275. It is moved by hand. The cost per ton manipulated, including interest on the outlay, is estimated to be fr. 0.30; 200 tons can be transhipped in 20 hours. By hand the time would be 30 hours and the cost fr. 0.40. In a year, 14000 tons of merchandise (coal, iron etc.) are lifted by the crane. The waggons are sent to the point of junction with the special connecting line of the port as in other stations.

(**N.**) — The 3610 tons which figure under private ports consist of 1572 tons shipped and 1217 discharged in open canal and of 821 tons furnished by a foundry at its own port.

Carried forward.	—	—	5,040	1,140	131,326	103,440	172,718	60,048	40,000

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay wall	with quay wall	Shipped.	Discharged	Public Port.	Private Ports.		
Brought forward	—	—	m. 5,040	m. 1,140	T. 111,426	T. 103,440	T. 172,718	T. 60,018	T. 40,000	
Public port of Void	11	104.	.	220	988	1,633	1,667	(c) 938	–	(c) Quay-wall built by the State. Unloading in open canal.
Port de Lacroix-le-pêcheur and of the soda works of Dombasle à Void	13	107.	—	100	43,893	—	—	43,893	—	(O) Quay-wall built by the soda works proprietors.
Public port of Troussey	13	110.5	100		382	1,132	1,514			
" " " Pagny s/Meuse	13	117.	230	100	375	50	425			Quay-wall built by the State.
" " " Lay St Remy	13	120.	120		195	94	289	–	—	
" " " Foug	14	122.	200		—	2,956	2,956	–		
" " " Ecrouves	21	126.5	100	—	227	2,583	812	(d) 1,998	—	(d) Unloading in open canal.
Toul (Porte de France)	25	130.	220	55	1,700	17,514	15,462	3,752	—	Quay-wall built by gas works. (P) 80 m. in open canal.
Toul (St Mansuy)	27	133.5	200		5	8,767	3,556	(e) 5,216	—	(e) Unloading in open canal by one manufacturer.
Toul (La Vacherie)	28	131.5	250		1,602	3,649	5,251			
Public port of Villey St Etienne	29	140.	100		18,682		18,682			(Q)
" " " Van de Moselle	30	145.	100	—	70,347	35	70,382	—	—	(R)
" " " Liverdun	30	148.5	425		16,870	354	17,224			(S)
Liverdun iron-works	Nancy reach	149.5	100	280	2,283	15,328		17,611		Quay-wall built by proprietors of iron-works and china works. (T)
Public port of Frouard	do.	154.	180*		993	4,483	5,476	—	650	(U) * 850 m. in open canal.
Carried forward.	—	—	7,365	1,895	290,838	162,154	319,579	133,413	40,650	

(O.) — Of the total 43893 tons of traffic 42371 consist of limestone shipped at a private port for the Solvay de Dombasle works, and 1522 tons of wood embarked at the port of Lacrois-le-pêcheur.

(P.) — Of the 15462 tons of the public port two firms contribute 4386 and 2373 tons respectively, or taken together 6759 tons. The 3752 tons of private ports comprise 1411 tons landed at the wharf belonging to the gasworks and 2341 tons landed in open canal.

(Q.) — This tonnage consists almost wholly of 16,587 tons of stone for the Solvay (Dombasle) works and 2025 tons shipped by another firm, making for the two firms alone 18682 tons.

(R.) — 39,315 tons (Solvay works); 23,359 (a local quarry), and other quarries 6812 tons, or a total of 69486 tons shipped by 3 firms alone.

(S.) — Of this tonnage 11133 tons are sent away by a quarry and 2227 tons by an iron-works, making for the two 13,360 tons.

(T.) — This comprises 2283 tons shipped and 13,329 landed by the iron-works; and 1999 tons contributed by the china works.

(U.) — A flour-mill receives 2844 tons. A shoe factory has a pivot-crane with adjustable arm which can be given a reach exceeding 15 m. It is used exclusively for landing raw timber. Its cost was fr. 5.000 and its lifting power is 10 tons. It is worked by hand, viz. 4 men on the loading stage and 2 men on the crane. The discharging of a boat of 200 tons occupies 3 days. The cost is given as fr. 0.40 per ton.

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged.	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward.	—		7,366	1,895	290,838	162,154	319,579	133,413	40,650	
Transhipment Port of Frouard.	Nancy reach	155		225	21,224	187	21,411		—	Quay-wall built by the State. (V).

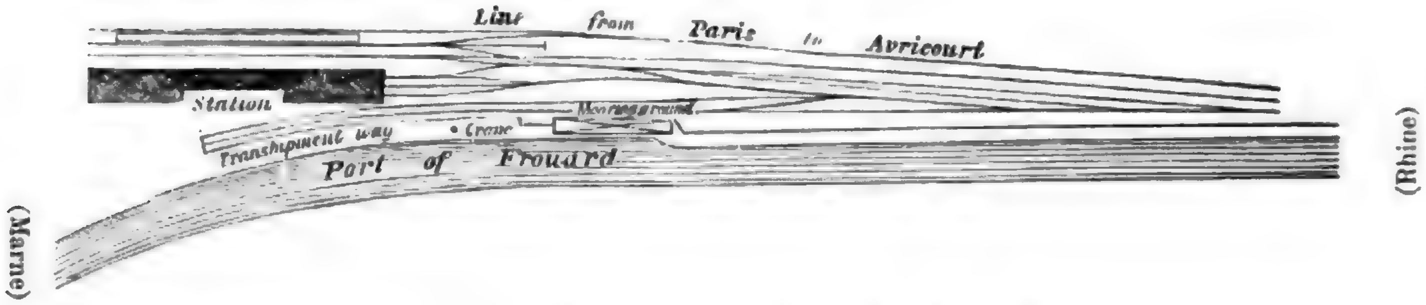
For topographical reasons dischargements cannot be effected by hand. The weight discharged is 650 tons per year approximately.

(V.) — The shipments consist almost exclusively of iron, both wrought and cast, and of steel from the Longwy metal markets, brought and delivered by train for transhipment to the boats. The wharf is 220 m. long and with the quay-wall is 10 m. wide; farther back are two permanent ways forming part of the siding and manoeuvring network of railways of the Frouard station and serving to connect the port with the general railway system. The level of these two ways is such that the floor of the trucks is level with the loading space.

A fixed crane on a pivot (for hand power), provided by the Eastern Railway Company, allows of goods being lifted from the trucks to be deposited there; the distance from the quay-wall is too great for direct transhipments between truck and boat; the goods must be deposited and re-handled. The cost per ton transhipped is, in consequence of these defects and the stationary character of the crane, too high and the system cannot be recommended. Except for specially heavy pieces difficult to handle otherwise, the crane is little used. Hand labour in the usual means of loading the boats, making the cost per ton of wrought or cast iron shipped amount to fr. 0.40 or fr. 0.50 for manipulation.

On the quay, a shed has been erected purposely for the transhipment service, but in reality serves for little else than a shelter for goods carried exclusively by railway.

In short, this wharf though presenting the inconvenience of being on the same bank as the tow-path is favourably situated; yet is it far from rendering all the service it is capable of, on account of its insufficient apparatus and its costly transhipment rates. The railway company for example reserves to itself the unloading of all wrought and cast iron, which is simply deposited on the quay, at a rate of fr. 0.30 per ton, whereas put directly on board the boat the additional cost would under



Carried forward.	—	—	7,365	2,120	312,062	162,341	340,990	133,413	40,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall	with quay wall.	Shipped.	Discharged.	Public Ports.	Private Ports.		
			m	m	T.	T.	T.	T.	T.	
Brought forward.	—		7,365	2,120	312,062	162,341	340,990	133,413	40,650	
Public Port of Champignelles, and rolling mills.	Nancy reach	157.5	107	134	10,587	22,993	970	32,616	·	Quay-wall built by mills.
Maxéville blast furnaces and Sarrebrück mines.	Nancy reach	160.	200	199	80,173	2,156	—	82,329	—	(W).
Public Port of Nancy (St. Sébastien and Vibilers).	Nancy reach	161.–	120	175	26,652	12,140	30,628	8,164	—	Quay-wall built by the State (X).
Port of Nancy (Malzéville).	Nancy reach	162.5	200	100	6,217	27,896	20,471	13,642	—	Quay-wall built by the State (Y).

other circumstances be about half, and with siutable apparatus the rate might be further reduced.

(**W.**) — This tonnage comprises 68,098 tons shipped and 2156 tons discharged from the blast furnaces and 12075 shipped from the mines. The Vézin Alnoyé Company who own the blast furnaces have a dock in which metal and ore are shipped and coke discharged. Hand labour with wheelbarrows is used for loading. The materials are removed from the storing or stacking ground behind the up stream tow-path, or otherwise from the small waggons of the Decauville railway which skirts the quay-wall. The cost of the labour is for metal fr. 0.20 to fr. 0.22 and for ore fr. 0.17. Near the quay-wall is a steam pivot-crane for unloading coke; this costs fr. 0.40 per ton; done by hand with baskets it costs fr. 0.60; yet the company who, although they are more favourably situated for railway carriage of goods, receive but little coke by water, have almost abandoned machine work in discharging on account of the resulting breakage and pulverisation of the fuel, which is considerably deteriorated for regular furnace use.

(**X.**) — Of the 30628 tons of traffic in public ports, 21968 and 3394 tons are supplied by two quarries, 4578 by a brewery, making for three firms only a total 29,940 tons. The 8164 tons under private ports are embarked or discharged in open canal and near their yards by 3 traders. The port of St. Sébastien is formed by a simple widening of the canal and has 175 m. of quay-wall, but no cranes or other appliances. The principal material loaded there is limestone (about 20000 tons a year) for the soda works. Fuel and building materials are discharged. Goods are deposited on the wharf within 5 m. of the top of the quay-wall. Fuel discharged from the boats in baskets by hand labour costs for this operation from fr. 0.30 to fr. 0.40. A turnpike road bounds the whole length of the wharf, to which access is had at the two extremities of the latter; this is extremely favourable for the distribution of goods from the port.

(**Y.**) — The 20471 tons figuring here under public ports comprise 6173 tons of stone delivered and embarked at the port by a single quarry.

Carried forward . . .	—	—	7,992	2,728	435,691	227,526	393,059	270,164	40,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	—	-	7,992	2,728	435,691	227,526	393,059	270,158	40,650	
Port of Nancy (Ste Catherine and St Georges)	Nancy reach	164.—	400	2,254	42,523	136,425	114,244	64,704	30,000	Quaywall built by State and private firms jointly. (Z).

The 13642 tons traffic of private wharfs comprise 2249 tons discharged by a dealer in fuel and 11393 tons, also discharged, by a bark and tannin factory, all effected in open canal.

The port of Nancy consists of a dock formed by widening the canal on the bank of the up-stream tow-path; the size of this basin is 100 m. by 17 m. It is entirely surrounded by quay-walls. The wharf is on the same level as the adjoining town railways.

Here are embarked yearly about 6000 a 7000 tons of goods, consisting mainly of limestone for the soda works, on the same terms as at St Sébastien.

The port has no cargo handling plant.

The timber (oak beams) is unloaded in the only existing permanent way and is thrown into a sunken road 3 m. below running between the canal and the above mentioned tannin extracting works for which it is intended. The timber is thence loaded on small waggons and taken to the storing place.

The cost per ton for unloading is fr. 0.50.

A boat of 180 tons is discharged by 6 men in 4 days without night work.

(Z.) The total traffic of public ports is thus distributed:

		Loaded.	Discharged.	
Port Ste Catherine	Nine large firms	12,146 tons.	32,449 tons.	
	Various	354 »	14,205 »	
Port St Georges	5 large firms	24,891 »	8,980 »	
	Various	795 »	20,424 »	
		38,186 tons.	76,058 tons.	
		114 244 tons.		114,244 tons.

The traffic of private ports, thus:

	Loaded.	Discharged.	
Nancy docks	3627 tons.	12,649 tons.	
St. Georges docks	239 »	4,686 »	
6 private firms	44 »	32,042 »	
A wood merchant's basin	427 »	4,887 »	
Docks belonging to the building yard	427 »	6,103 »	
	4,337 tons.	60,367 tons.	
	64,704 tons.		64,704 »
Making a total of			178,948 tons.

The two ports of Ste Catherine and St Georges, separated by a national road, form the real ports of Nancy. Plate VI gives the topography of the port. The wharfs all have bordering quay-walls.

Carried forward	—	—	8,392	4,982	478,214	363,951	507,303	334,862	70,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	—	—	8,392	4,982	478,214	363,951	507,303	334,862	70,650	

The S^{te} Catherine basin formed by a widening of the canal on the side of the up-stream tow-path is 175 m. long and has a width of 35 m. beyond the 18 m. of the main channel.

Wood and other combustibles, building material and wine are the commodities landed here. Ore and limestone are shipped.

The only apparatus at the port is a timber-built platform on wheels and rails; it carries a windlass. The apparatus serves merely for landing wine in barrels and is little used (about 100 tons per year). The entrepôts of which we shall presently speak now nearly all do similar work.

On the ground space belonging to the port, the gas works, which are contiguous, have a narrow guage line for small waggons serving for the discharge and delivery of their coal supply; the coal is thrown directly from the boat into the waggons brought alongside on the top of the quay-wall. The company's conditions and prices are not made public. It is however estimated that it must cost something like fr. 0,25 per ton.

S^{te} Catherine's Port has an annex consisting of a basin 55 m. by 10 m. on the tow-path side of the canal, and in the service of a general timber merchant. Timber in the rough, arriving in rafts or by boat (4000 to 5000 tons yearly), is received and handled in this basin. It is stacked by hand, or heavy logs by a floating crane belonging to the merchant. This crane is taken long distances to ship timber at the point of production and serves also to discharge the cargo on arrival.

The cost of this labour is difficult to estimate; it depends greatly on the size of the timber, as well as on the skill of the workmen; it may be put down at from fr. 0.30 to fr. 0.40. Without the crane the rate would be considerably higher and some of the work would be impossible.

The S^{t} Georges basin also is formed by a widening of the canal. It is on the up-stream bank and is 224 m. long and 40 m. wide. All kinds of building material, chiselled stone, wood etc., also corn, fuel and various wares are brought by boat and discharged here.

On the principal ground space is a travelling metallic platform on rails carrying a 10 ton travelling winch.

This machine belongs to a private merchant who by virtue of the conditions of this special, but revocable, authorisation is obliged to lend the use of the apparatus to the public and to load or unload boats in the order of their arrival. Its vocation is largely confined to the manipulation of often recurring shipments of heavy building stone, which without it it would be impossible to handle. The canal management however is in spite of the conditions imposed still without sufficient authority for the due control of terms made to the public by the owner.

Carried forward.	—	—	8,392	4,982	478,214	363,951	507,303	334,862	70,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	-	.	8,392	4,982	478,214	363,951	507,303	334,862	70,650	

In case of inconvenience or disagreement it could require the apparatus to be removed; but in the absence of any other it does good service (from 10000 to 12000 tons yearly) and is consequently retained.

On the tow-path side of the canal and adjoining its dependencies are also 3 important annexes, viz. 1 The Nancy docks and warehouses; 2 St. Georges dock; 3 The building material docks.

The Nancy docks and warehouses are used principally for discharging corn and wine, and the boats of the Porteurs de la Marine bring into them and discharge retail articles and comestibles. This company occupy 20000 sq. m., their principal building standing at right angles to the canal. The first floor of this building is continued by a platform extending over the tow-path and adjoining ground space, and carrying a steam pivot 1500 ton crane at its extremity. By means of this crane barrels are lifted from the boats to the wharf, also corn in bulk is discharged by it in small waggons or wheeled bins which are placed directly either on rails close to the crane or on its platform, or on the ground floor where an entrance to the building has been made for dealing with corn in sacks and other packed retail goods. The same apparatus can also effect direct transhipments to waggons at the extremity of an ordinary guage way parallel to the warehouse and in running connection with the Nancy circular railway.

The cost per ton for discharging wine cargoes is fr. 0.25; corn in bulk costs fr. 0.40; done by manual labour only, 50 % more.

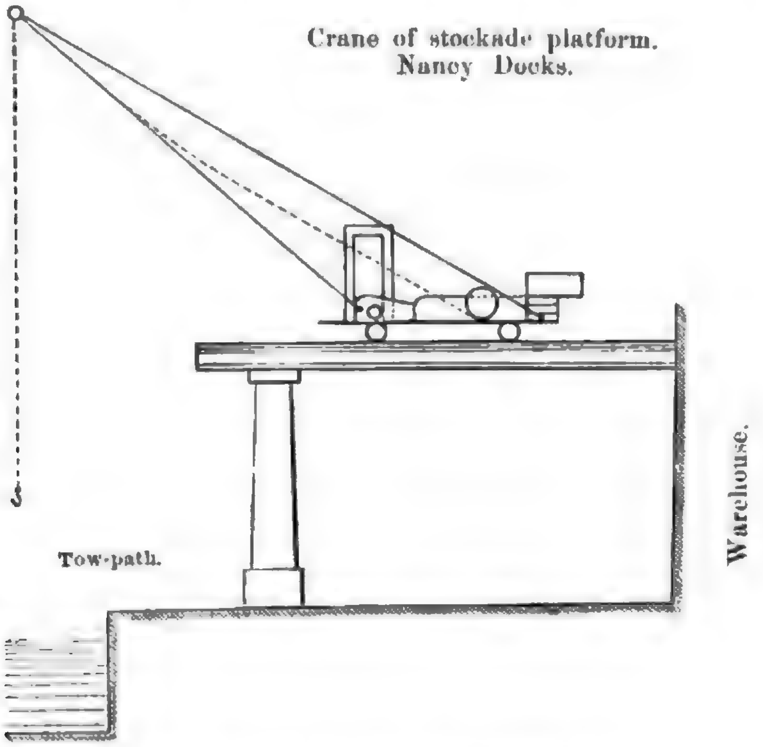
The St. Georges docks have 1473 sq. m. of ground space of which 1000 m. is occupied by covered warehousing. Wine forms the staple traffic. There are two manual pivot cranes of ½ and 2 ton power respectively, of which one is on rails running perpendicular to the canal and allowing of its being advanced towards the quay-wall or withdrawn into the warehouse; the other is moveable on the ordinary rollers of the wharf. The cost of unloading and depositing either on the wharf or on vehicle is, for wine in barrels or other goods easily handled by the crane, fr. 0.30 and for smaller objects or retail wares fr. 0.40.

The building-material docks have an area of 8285 sq. m.; of this 100 sq. m. are occupied by covered warehouses. As the name implies, its principal trade is building-materials. As with the Nancy docks here too is a private basin with mooring space for two boats. Over this basin is a platform-bridge with a 10 ton crane, as at the public port for discharging stone. Similar articles and other goods are discharged by this apparatus, amongst them lime in bags, bricks, tiles, which are lifted from the boat on to platforms and similarly placed on trucks or waggons.

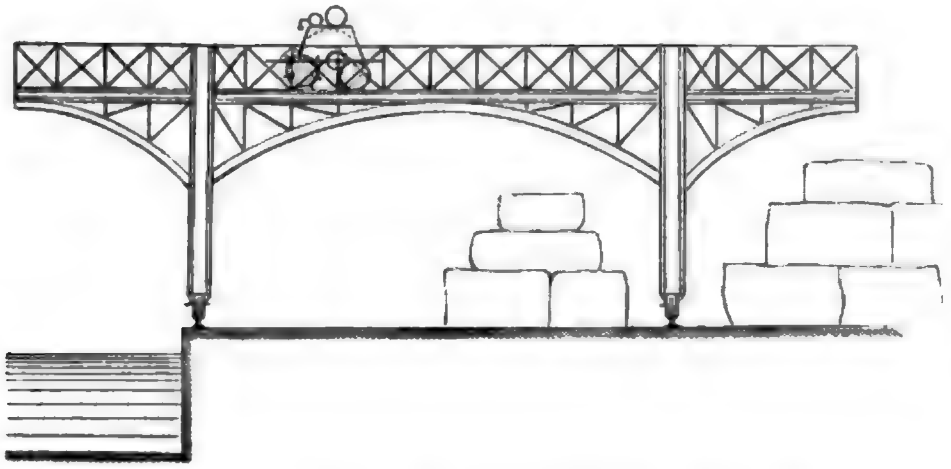
Carried forward	—	—	8,392	4,982	478,214	363,951	507,303	334,862	70,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			with-out quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	–	–	8,392	4,982	478,214	363,951	507,303	334,862	70,650	

The basin is in connection with the circular railway; the connecting line of permanent way skirts the basin and thus allows of direct transhipments to be effected.


Crane of stockade platform.
Nancy Docks.

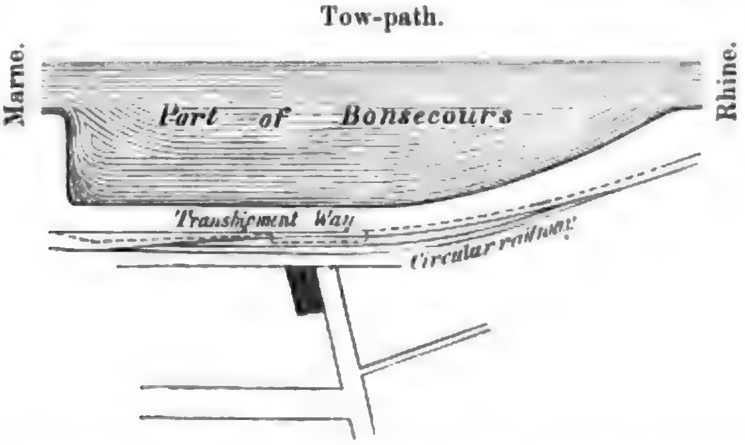
Bridge with winch for discharging building stone.



Carried forward.	–	–	8,392	4,982	478,214	363,951	507,303	334,862	70,650	

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m	m	T.	T.	T.	T.	T	
Brought forward	—	—	8,392	4,982	478,214	363,951	507,303	334,862	70,650	
Public port of Bon Secours.	Nancy reach	165.5	240 80		310	14,695	7,029	7,976		(A A.) The 80 m. in open canal.
Jarville blast furnaces	Nancy reach	166.5		160	50,111	10,336	-	60,447	—	(A B) Quay-wall built by the works
Public port of Jarville, waggon works	do. and 26	166.2 to 167.	215	—	—	1,378	1,378	—	—	

(A A.) — The traffic under private ports comprises 4949 tons discharged in open canal by a timber merchant and 3027 tons for a spinner, also discharged in open canal. The port communicates with the Nancy circular railway by a public transhipment line:



By the Company's tariff regulations the port is open for transhipments per full waggon only; traders and others must effect their own transhipments and are charged fr. 0.20 per ton for station accomodation. The rails are 14 m. from the edge of the mooring siding, which is not walled. There is no cargo handling plant. The traffic in transhipments is almost *nil.*

(A B.) — The port serving these blast furnaces is formed by a simple quay-wall along the bank of the open canal and on the same side as the tow-path. There is mooring space (160 m.) for four boats. The floor level of the wharf is 1.70 m. above the water-level. The traffic consists of shipments of cast iron and discharging of coke. The coke is taken from the boat in baskets and deposited beyond the tow-path on ground belonging to the works. The cost of this labour is fr. 0.60 for the lower layer and for each successive layer an additional fr. 0.05 per ton For iron unloaded by means of wheelbarrows the cost is fr. 0.20 and upwards according to distance. There is an inclination to adopt mechanical appliances; but hitherto the heavy first-cost has prevented its realisation.

Carried forward	—	—	8,927	5,142	528,635	390,360	515,710	403,285	70,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay wall	with quay wall	Shipped	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	—	—	8,927	5,142	528,633	[illegible]	515,710	402,285	70,650	
arville blast furnaces (up stream)	26	167.5		155	61,347	17,511		60,858		(A C) Quay-wall built by the works.
t Valdrée salt works	25	168	40	—	1,266	1,500	—	2,766	—	Discharged in open canal.
ublic port of Laneuveville	26	168.5	75	—	105	784	889	-	-	
[illegible]serville salt works	25	169	40	—	—	3,774	-	3,774	—	Discharged in open canal.
russian blue works	25	171	40		—	3,005		3,005		Discharged in open canal.
ublic port of St Phlin and Laneuveville salt works	24	172	132 and 80	-		1,988	54,883	—	40,000	These 80 m. in open canal (AD).
Madeleine soda works	24	172.5			6,277	46,637				
rt sur Meurthe salt works	24	174		88	12,108	6,522		18,630	—	(A E) Quay wall built by the salt works.
St Nicolas Varangeville salt works	24	176	—	241	23,174	7,937	—	30,841	30,000	Quay-wall built by the salt works (A F

(A C.) — This port is worked similarly to the above named blast furnaces **(A B)**. It is on the up-stream side of the canal.

(A D.) — Though public, this port derives its traffic from two establishments; this traffic consists of combustible material (coal) and of limestone, both in-coming; there is no quay-wall to the basin, but a portion of the bank is faced with upright timber. In virtue of a terminable authorisation, the proprietors of the works have placed a travelling steam-crane on rails on the wharf; it is however of old pattern and unsatisfactory.

Coal discharged and stacked on the storing space costs for labour fr. 0.20; limestone delivered at the works also fr. 0.20 per ton.

The proprietor proposes to supersede the existing crane by a more perfect mechanical apparatus capable of both discharging and housing cargo.

(A E.) — Combustibles discharged and rock salt loaded by hand and wheelbarrows, or with rollers on trestle-supported platforms or runs along the deck of the boat.

Combustibles discharged cost fr. 0.70, and salt loaded, fr. 0.20 per ton. From boat to storing place is about 50 metres.

(A F.) — The wharf belonging to this establishment is on a mooring siding for one boat, effected by a simple widening of the canal.

Coal is discharged and rock salt loaded on the tow-path side of the waterway. A steam 3 ton pivot crane on the end of a platform at right angles to the canal and 8 metres above its water-level serves for discharging coal. This is

Carried forward	—	—	9,324	5,576	814,912	470,729	571,482	523,159	140,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	—	—	9,324	5,576	614,912	479,729	571,482	523,159	140,650	
Public port of Varangeville. . .	24	1.765	—	182	82	11,116	11,193	—	—	Quay-wall built by State.
Transhipment port of Varangeville.	24	1.765	—	465	6836	43,337	50,173	—	—	(A G).
Carried forward . .	—	—	9,324	6,223	621,830	534,182	632,848	523,159	140,650	

done in 1 ton bins, which the crane lifts from the boats, carries across the tow-path and places on the train of waggons on the platform.

These are tipped and the coal stacked 50 metres away.

In 20 hours a *péniche* is discharged by 8 men at a cost of fr. 0.30 per ton.

Crushed salt loaded in bulk is run over the boat in small waggons on superposed platforms and tipped into fixed hoppers.

Salt in sacks is put on board boats by a shoot from a trapped platform serving also to load waggons; the canal and the connecting line between the works and the railways are contiguous here.

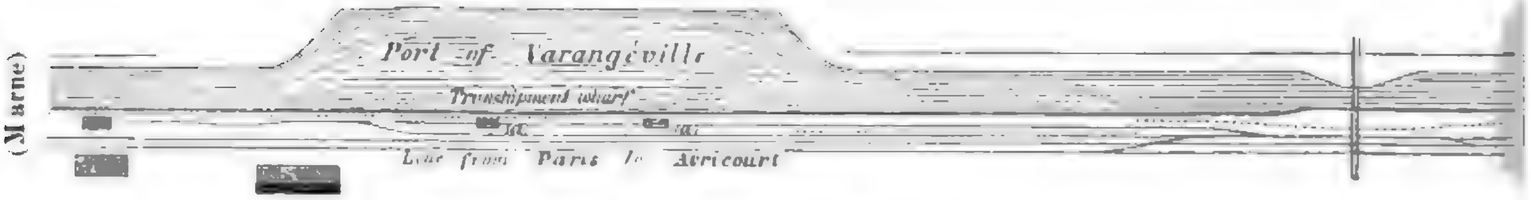
The cost of shipping crushed salt as bulk cargo taken from the warehouse 100 yards away is estimated at fr. 0.26; 8 men can thus load a *péniche* in 18 hours.

Taken from waggons at the entrance to the platform and embarked, the cost is fr. 0.23 or fr. 0.24.

Rock salt brought in carts or other vehicles alongside the quay-wall is also shipped by the works at a cost, for transhipment from vehicle to boat, of fr. 0.23 to fr. 0.24 per ton.

(A G.) The transhipment port of Varangéville is by its situation an excellent example of a port of junction of canal and railway.

At this point all goods for the Vosges valleys must perforce leave the canal; and inversely all products from those valleys may be here transhipped from rail to water. Unfortunately there exists neither ground space nor apparatus. The mooring water consists of a narrow but long gap made in the upstream bank adjoining the Varangéville station. A siding or supplementary line belonging to the station serves as a transhipment line and is but 3 metres from the top of the quay-wall. Then comes the main permanent ways ot the Paris—Avricourt railway.



(a) Sheds for transhipped salt.

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	—	—	9,324	6,223	621,830	534,182	532,853	523,159	140,650	
Meurthe Soda works	23	177.3		160		18,692		18,692	18,000	(AH). Quay-wall built by the works.
Rosière Varangeville salt works	23	177.5	—	206	23,542	5,393	—	28,935	20,000	(AI). Quay-wall built by the works.
Dombasle soda works (Solvay and Co).	23	178		430	58,136	405,534	—	463,670	290,000	(AK).

The port has no plant; coal, stone, salt, of which the traffic mainly consists, are transhipped by hand with either wheelbarrows or rollers. It is undertaken by the merchant himself and must be direct from boat to rail, or vice versa, on account of the non-existence of warehouse or ground space. From the merchant is due to the railway station expenses for waggons delivered.

The transhipment of coal from boat to waggon costs fr. 0.40, station expenses not included; salt from boat to waggon costs fr. 0.35, the salt being mainly in sacks.

A ton of *trapp* costs from waggon to boat fr. 0.20 to fr. 0.25.

(**A H.**) — This establishment has a wharf 160 m. long, along a widened canal stretch. A frame work or scaffold-platform extending over the tow-path carries a travelling winch by which small waggons can be transferred from the boat to the line of railway serving and entering the works. Electricity is the motive power for this winch; a receiving dynamo in a cabin on the platform commands all its mechanism.

(**A I.**) — This salt factory possesses a quay which is a prolongation of that of the adjoining soda works and exists under the same conditions. Two stockade-platforms at right angles to the canal serve for embarking rock-salt This is run to the extremity of the stockade in small waggons on rails arranged in such manner that the centre of gravity of the burden carried is on the rotatory axle. The waggon is tipped by a workman at a hopper and the salt falls into the boat.

(**A K.**) — Of all the different works which contribute traffic to the Marne au Rhin Canal Messrs Solvay and Co.'s establishment is by far the most important. Its dock is formed by a widening of the canal to accomodate a line of boats along 430 m. of quay-wall on the up-stream bank; its excellent and powerful apparatus allows of a high figure of tonnage being embarked and discharged. In 1893 its total was 463670 tons, or more than a quarter of the total of all the ports combined between Vitry le François and Xures.

The total 463670 is made as follows:

Shipments of manufactured products, salts or soda	58,136 tons
Boat deliveries of combustibles	142,207 »
» » » lime	262,137 »
Various	1,190 »

Carried forward	—	—	9,324	7,019	703,508	963,801	532,853	1034,456	468,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m	m.	T.	T.	T.	T.	T.	
Brought forward	—	—	9,324	7,019	703,508	963,801	632,853	1034,456	468,650	

The plant of the port comprises (see plan and details of appliances Plate VIII):

(*a*) A small stationary pivot crane, used for handling odd cases and packages and only mentioned for the sake of order.

(*b*) A cable apparatus (see fig. nº. 2) for discharging coal which is to be stored. The combustible is first lifted vertically, then at a suitable height carried horizontally across the high road running between the works and the canal to the place where it is to be landed. The system and principle regarded as a whole consists of a supporting cable stretching from the top of a metallic stockade (N) to a second frame work over the boat to be discharged. On the cable runs a small waggon with an arrangement of levers and catches allowing of a 10 cwt. waggon being attached. The waggon is propelled by a traction rope winding on the drum of a steam winch; a catch permits the waggon to descend automatically into the boat and when refilled to rise again; it follows the horizontal cable to the desired point where a stop catch provokes its discharge, and a counter-balancing arrangement causes its return. All the manoeuvring is regulated and controlled from the cabin (N) which corresponds by conventional signs with the gang of labourers.

By this arrangement 250 tons of coal and other fuel can be discharged in 15 hours.

All hand labour and working expenses for unloading amount to between fr. 0.22 and fr. 0.26 per ton.

The first outlay for the apparatus was approximately fr. 60,000.

(*a*) A stockade platform with a series of cranes constituting the essential feature of the port's equipment.

The stockade (AB) parallel to the canal is fixed on the wharf between the top of the quay-wall and the main road (see plan, Pl. VIII figs. 1, 3, 5, 6). It is 240 m. long. Its floor is 7.96 m. above the water-level and 7.60 above the road level. At different points on projecting foot bords are 10 hydraulic cranes of 1200 kg. (25 cwt) power for discharging rough material from boat to waggon, or reciprocally to put on the water the products of the works.

Two metal bridges run from the works, one across the high road (C D of the plan) to the canal and the other across both the high road and the canal (E F of the plan), and connecting the two groups of workshops on opposite sides of the canal.

The small waggons consist of loose bins, on fixed platforms on wheels. The bins are lifted by the cranes into the boats and when filled are returned by the same means to their trucks. On the stockades and bridges are two lines of rail for full or empty waggons.

Limestone is mostly directed upon the bridge which spans the canal, and at the end of this by a hydraulic lift raised to a maximum of 1 or 10 m. and tipped, or otherwise distributed in the lime works (see plan fig. 4).

Carried forward	—	—	9,324	7,019	703,508	963,801	632,853	1034,456	468,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machines.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Discharged	Public Ports.	Private Ports.		
			m.	m.	T.	T.	T.	T.	T.	
Brought forward	–	–	9.324	7.019	703,508	963,801	832,853	1034,456	468,650	

Combustible materials too are directed towards these same works or to the bridge spanning the high road; at the end of the bridge they are either stored or tipped into hoppers which feed other raised waggons running to different parts of the works.

Manufactured products should pass mainly by the bridge C. D., but as this part of the establishment is not yet completed most of the output is shipped by shoots, these running from the platform down into the boats, or by wheelbarrow and hand labour are deposited upon the lower wharf.

In 1893, the first year's normal working of the apparatus just described, the hydraulic cranes served for the discharging of 250,000 tons.

The cable arrangement near it landed 40000 tons. The surplus of goods loaded or discharged is for the most part run across the public road in wheelbarrows, but this means, formerly the only one employed, is destined to shortly disappear.

The cost of discharging cargo by the cranes is estimated to be as follows:

For limestone:

1. Bins put on trucks, near the cranes, including care	fr. 0.24 to fr. 0.28 p. ton
2. Bins carried, discharged, and returned to and from the storing place according to distance and level, from	„ 0.45 „ „ 0.60 „ „

For coal:

1. Bins put on waggons from	„ 0.22 „ „ 0.26 „ „
2. Bins taken to storing ground or hoppers, and brought back	„ 0.27 „ „ 0.32 „ „

For Coke double the cost of coal should be counted; with two cranes working a 250 ton boat can be discharged in 5 hours.

For discharging cargo by wheelbarrow the cost may be calculated as follows:

For limestone:

1. Taken from boat and conveyed 2 stages on the level	fr. 0.35 to fr. 0.40 p. ton
2. Tipped in a heap, according to distance and level.	„ 0.50 „ „ 1.0 „ „

For Coal:

Taken from the boat and run 2 stages on level ground	„ 0.38 „ „ 0.40 „ „
Stored, according to distance and height	„ 0.60 „ „ 0.80 „ „

For coke, here also double the cost of coal.

Carried forward	–	–	9,324	7,019	703,508	963,801	832,853	1034,456	468,650

Names of Ports and Industrial & Commercial Establishments.	No. of reaches.	Kilometric position.	Length of Bank for Loading and Unloading.		Goods.		Total Traffic.		Tonnage handled by machinery.	OBSERVATIONS.
			without quay-wall.	with quay-wall.	Shipped.	Landed.	Public Ports.	Private Ports.		
Brought forward	—		m. 9,324	m. 7,019	T. [illegible]	T. [illegible]	T. [illegible]	T. [illegible]	T. 468,650	
Public port of Dombasle	23	178,6	100	—	—	4,512	4,512	—	—	
Dombasle salt works	23	178,6	—	47	112	2,532		2,644		Quay-wall built by the works unloading in open canal.
Public port of Somerviller	22	180,5	75		18	866	884			
Somerviller salt works	21	181,5		78	13,052	4,694		17,746	—	do.
Crévic salt works	21	181,6		43	3,092	1,084	—	4,176	—	do.
Public port of Crévic	20	184,	100	—	174	845	1,019	—	—	
Maixe salt works	20	186,		88	5,408	2,936		8,344		Quay-wall built by the works.
Public port of Maixe	20	187,3	105			1,128	1,128			
Einville salt works	19	189		95	6,375	2,586		8,961		(AL) Private port built by the Salt works.
St Laurent-d'Einville salt works	18	190,5		110	32,875	7,471		40,346	32,000	Quay-wall built by the works. (AM)
Public port of Einville	18	190,7	—	110	868	3,953	4,821	—	—	Quay-wall built by the State.
" " " Beauzemont	18	194,8	110			208	208	—	—	
" " " Hénaménil	17	197,4	115		704	563	1,267		—	
" " " Parroy	16	201,	119		1,070	1,476	2,546			
" " " Mouacourt	15	203,5	112		454	827	1,281			
" " " Xures	15	205,5	153 40		88	345	433	—	—	(AN) The 40 m. in open canal.
Total	—	—	10,344	7,590	767,702	997,559	550,641	111,462	500,650	

To discharge a boat by hand labour with wheelbarrows takes about three times the time that is requisite when cranes are used.

The cost of the platforms, cranes and accessories, buildings and machinery, not including any part or apparatus of the works proper, is estimated to have been approximately fr. 400,000.

(**A L.**) Loading and unloading operations are effected in a private dock 95 m. long by 6 m. wide.

(**A M.**) This salt works establishment possesses on the up-stream tow-path a 110 m. stretch of quay-wall and wharf.

A stockade bridge spans the tow-path on the floor level of the works and serves for embarking rock salt by means of hoppers and other appliances. Taken up to the entrance to the works on small waggons and shipped the cost is estimated at fr. 0.135 per ton. Shipment of salt in sacks from the warehouse 120 m. away costs fr. 0.62 per ton. Coal is discharged by wheelbarrow and together with its storage 25 m. from the canal costs for labour about fr. 0.40 per ton.

(**A N.**) In a private basin 40 m. by 15 m. adjoining the port of Xures, the collieries of Le Nord and of Belgium operate transhipments of coal for the districts served by the shallow canals of Alsace-Lorraine. By means of shovels, the coal being simply thrown, it costs fr. 0.35 per ton approximately.

Summary and Observations.

The foregoing descriptions give a complete idea of the functionoof the Marne au Rhin Canal ports and enable us to estimate its working.

From the figures given the following results may be drawn.

Of a total traffic of 767702 tons shipped and 997559 discharged, together 1765261 tons, 500650 tons are manipulated by more or less perfect mechanical appliances such as cranes, winches, stockades etc.; almost all these appliances are on private wharfs.

Of the 1765261 total, 1114620 tons are handled on private wharfs or in open canal for private building yards or works.

The traffic of public ports on the other hand reaches 650641 tons.

On examining the tables given it will be found that of this, 370818 tons are furnished by the limited number of 43 wholesale transport firms, manufacturers or merchants, making an average of 8620 tons approximately for each of these principal traffic contributors.

If from the total tonnage of public ports the 370818 just mentioned be deducted, there results 73823 tons transhipped in 3 junction ports and 205995 tons of miscellaneous goods which may be considered as the traffic really contributed by the general public and as resulting from a multitude of various and individually undefinable interests.

This tonnage of 205995 tons is spread over 69 public ports giving an average for each of 3433 tons; continuing still further our analysis we find that of this same tonnage 35778 tons must be attributed to the individual ports of S^{te} Catherine and S^{t} Georges, Nancy.

49071 to four ports with from 10000 to 15000 tons each, viz. Bar-le-Duc, Menaucourt, Nancy, Malzeville and Varangeville, the general average being 12268 tons for each of these ports.

48466 must be credited to 7 ports yielding from 5000 to 10000 and averaging together 6924 tons, viz. Revigny, Ligny, Houdelaincourt, Mauvages, Toul (porte de France), Toul (La Vacherie) and Nancy (Bonsecours).

Finally 72680 to 48 different ports of less than 5000, and averaging 1514 tons.

The cost of the several operations in handling traffic varies greatly for different goods; comparison too is difficult on account of the dissimilarity of means employed and result sought for in each port.

The following table, without fixing rates absolutely, gives an approximate idea of what has in practice been realised.

	SHIPPED.					LANDED.						
	Ore.	Salts.	Limestone.	Pipes.	Various.	Coke.	Coal.	Limestone.	Hewn stone.	Comestibles.	Timber.	Various
	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.
By hand	—	—	—	0.80	0.30–0.50	0.60	0.40	—	—	0.50	0.50–1.	0.55
With wheelbarrow . . .	0.30	0.20–0.25	0.20	—	0.30–0.50	—	0.35	0.35	—	—	—	0.55
By waggon on quay . . .	0.20	0.20–0.25	—	—	0.20	—	0.35	—	—	—	—	0.40
» » » platform .	0.15	—	0.15	—	—	0.45	—	0.25	—	—	—	—
» tipping waggon . . .	0.10–0.06	0.15–0.20	0.10	—	—	—	—	—	—	—	—	—
By manual crane . . .	—	—	—	0.60	—	—	0.35	—	—	0.35	0.30–0.40	0.30
» steam or hydraulic crane .	—	—	—	—	—	0.45	0.25	0.24	—	—	—	—
» special apparatus . .	0.10–0.05	0.135	0.10–0.05	—	—	0.20–0.30	—	—	0.40	—	—	—

These figures apply to operations of a certain importance, eliminating all work not pertaining to cargo-loading or discharging proper. Under these conditions they shew that the use of mechanical appliances generally secures economy, but that the saving is greatest when it is possible to have apparatus specially suited and exclusively intended for a determined class of merchandise, which is possible only in private or in very large public ports.

With regard to rapidity and facility of operations the gain is great, more important perhaps than the gross and not always easily estimated monetary differences of cost. It may also be remarked that in the examples given above the time required for loading or for discharging a boat by mechanical means is only one third or one half that required for the same work done by hand. Often the gain is still greater. Moreover the number of labourers required is notably lessened. The economy of time and men is generally the most predominant question in questions pertaining to the equipment of large public as well as private ports.

These figures and summarised explanations seem to furnish a justification for the general considerations referred to at the commencement of this Paper, especially in what has relation to public ports, their needs and their possible classification. It is on these grounds that we have produced it.

CONCLUSIONS.

As a conclusion to the general considerations developped in the present Paper and of the facts observed in a large number both of public and of private inland navigation ports we judge it useful to complete as follows the resolutions adopted by the Vth Congress (Paris 1892).

After art. 2 there should be added 3 paragraphs which we word as follows:

2a. In each port the development to be given to the plant should depend upon the importance and real needs of the port.

In important ports destined to have a complete plant (railways, sheds, warehouses, cargo-handling appliances) this plant should be established upon a general plan, so that the different constituent elements shall be in perfect relation to one another.

The plant of the navigable way proper should include special appliances for embarking and discharging merchandise and packages of exceptional weight or dimensions at all points where such appliances are likely to be serviceable.

Again we propose to append to article 3:

3a. Private apparatus may be authorised in public ports, provided its existence be not contrary to general interests.

To promote the development of plant, private initiative should as far as possible be favoured and encouraged.

In unimportant ports all apparatus and outlay not fully justified should be avoided. Here private initiative seems particularly liable to give satisfactory economic results. Assistance should however be afforded by simplifying to the fullest possible extent all formalities necessary for fixing and working plant.

For important ports as well as for special plant, for handling pieces of exceptional weight, public bodies may, in the absence of private enterprise, usefully intervene and concur, either directly or through authorised persons. Concessions relative to plant must emanate from the central body.

To all authorisation given for plant must be appended a maximum tariff, under which the plant shall be at the disposal of the public, without favour or preference.

It is important moreover, that stress be laid upon the temporary and revocable character of the conditions of authorisation of the plant.

Paris and Nancy, April 25th 1894.

Inscriptions des Planches. Inschriften der Zeichnungen. Description of Plates.

PLANCHE I.	BLATT I.	PLATE I.
Mines de Lens et de Liévin.	**Gruben von Lens und von Lievin.**	**Lens and Lievin Mines.**
Glissières d'embarquement.	Gleitbahnen.	Loading shoots.
Fours à coke.	Kokesöfen.	Coke ovens.
Maison du préposé.	Haus des Vorstehers.	House of officer in charge.
Pont de halage.	Leinpfadbrücke.	Tow-path bridge.
Appareil de transbordement.	Umschlagapparat.	Trans-shipping apparatus.
Voie principale.	Hauptweg.	Principal way.
Wagons vides.	Leere Waggons.	Empty waggons.
Vente par voiture.	Verkauf in Wagenladungen.	Sale by waggon-load.
Maison du chef de quai.	Haus des Kaivorstehers.	House of wharf master.
Mines de Béthune.	**Gruben von Béthune.**	**Béthune Mines.**
Voie de service réliée à la ligne de	Anschlussgeleis an die Eisenbahn	Railway connected with the line of .....
Voies desservant les voies de triage.	Zu den Rangirgeleisen führende Geleise.	Lines serving sorting lines.
Voies de triage.	Rangirgeleise.	Sorting lines.
Culbuteurs automatiques.	Geleise für die Ladung von Holz und die Einschiffung von gesiebten Kohlen.	Automatic tilting waggons.
Voie de chargement de bois et embarquement de cribles.		Line for loading wood and sifted coals.
Chaîne de tonage et pompe alimentaire.	Zugkette und Speisungspumpe.	Sunken chain and feeding pump.
Bascules.	Waagen.	Weighing machines.
Dépôt de bois.	Holzlager.	Timber ware-house.
Fours à coke.	Kokesöfen.	Coke ovens.
Charbonnages d'Anzin et Forges de Denain.	**Kohlengruben von Anzin und Hüttenwerke von Denain.**	**Anzin colliery and Denain iron-works.**
Verrerie.	Glasfabrik.	Glass-works.
Chemin latéral.	Seitenweg.	Side-road.
Sentier.	Fusspfad.	Foot-path.
Plan d'ensemble des ports.	Gesammtansicht der Häfen.	Comprehensive projection of ports.
Gares d'eau des Charbonnages d'Anzin.	**Hafenbecken der Kohlengruben von Anzin.**	**Water stations of the collieries of Anzin.**
Dépôt de Combles.	Stätteplatz.	Space for deposit of goods.
Mélangeur.	Mischapparat.	Mixer.
Quai aux charbons.	Kohlenwerft.	Coal wharf·
Embarquement à la grue.	Einschiffung mit Krahnen.	Shipment by means of cranes.
Embarquement des briquettes et des gailleteries à la main.	Einschiffung von Press- und Nuss-Kohlen durch Handarbeit.	" of briquettes and nuts, by hand.
Halle de dépôt de gailleteries.	Lagerschuppen für Nusskohlen.	Ware-house for nuts (coal).
Forges et hauts fourneaux.	Eisenwerke und Hochöfen.	Iron works and blast furnaces.
Pont tournant.	Drehbrücke.	Swinging bridge.
Bras de décharge.	Abflussarm.	Over-flow passage.
Entrée des bateaux.	Einfahrt der Schiffe.	Entrance for boats.

MONET & DARDENNE.

Mines de Noeux.	**Gruben von Noeux.**	**Noeux Mines.**
Rigole de dessèchement.	Entwässerungsgraben.	Trench for drying purposes.
Gare de triage.	Rangirbahnhof.	Sorting station.
Employés du rivage.	Werftbeamte.	Lightermen.
Estrade.	Ladegerüst.	Platform.
Bassin de virement.	Ausweich- (Wende-) Becken.	Turning basin.
Voie venant des fosses.	Von den Gruben kommendes Geleise.	Railroad coming from the pits.
Machine élévatoire alimentant les fosses.	Hebemaschine, welche die Gruben bedient.	Elevating machine for feeding the pits.
Ecurie.	Stall.	Stables.
Pont levis.	Aufziehbrücke.	Draw-bridge.
Charbons en dépôt.	Kohlenlager.	Stacked coal.

Mines de Courrières.	**Gruben van Courrières.**	**Courrières Mines.**
Chemin de halage.	Leinpfad.	Tow-path.
Aqueduc.	Aquaeduct.	Aqueduct.
Pont fixe.	Feste Brücke.	Stationary bridge.
Mur de quai.	Kaimauer.	Quay of masonry.
Machine du touage.	Schiffszugmaschine.	Sunken cable for movement of ships.
Bascule.	Waage.	Weighing machine.
Château d'eau.	Wasserstation.	Water Station.
Voie directe.	Durchgehendes Geleis.	Direct Line.
„ de manoeuvres.	Rangirgeleise (zum Ueberführen auf andere Linien etc.).	Line for manoeuvring trains.
„ de triage et de composition.	Rangirgeleise (zum Sortiren von Waggons und Zusammenstellen von Zügen etc.).	Line for sorting and making trains.
Voies des trémies.	Ladetrichtergeleise.	Funnel lines.
„ des grues.	Krahngeleise.	Crane „
Voie pour la vente au comptant.	Geleise für den Verkauf gegen Baarzahlung.	Line for (cash) sales.

Mines de Bruay.	**Gruben von Bruay.**	**Bruay Mines.**
Limite des terrains de la Cie. des Mines.	Grenze des Geländes der Grubengesellschaft.	Boundary of land owned by mining Co.
Voies ferrées reliant les fosses au canal.	Geleise zwischen den Gruben und dem Kanale.	Railroads connecting the pits with the canal.
Maison d'habitation du Chef du rivage.	Wohnhaus des Werftvorstehers.	House of the wharf master.
Maisons de gardes.	Aufseherhäuser.	Keepers' houses.
Dépôt pour la vente en détail.	Niederlage für den Kleinverkauf.	Warehouse for retail sales.
Hangar pour déposer du charbon.	Kohlenschuppen.	Shed for storing coal.
Bassin pour l'embarquement des charbons.	Becken zum Einschiffen von Kohlen.	Dock for shipment of coal.
Terrain pour déposer les stocks de la Compagnie du Gaz Parisien.	Lagerplätze für die Vorräthe der Pariser Gasgesellschaft.	Ground for storing the stock of the Paris Gas Works Co.
Château d'eau.	Wasserstation.	Water station.
Maison d'habitation de l'affreteur.	Wohnhaus des Verfrachters.	Freighter's house.
Bassin pour le déchargement des bateaux de bois et divers.	Becken zum Ausschiffen von Holz und anderen Gütern.	Dock for unloading timber and other boats.
Terrain pour les dépôts de bois.	Holzlagerplätze.	Ground for storing timber.
Basculeurs hydrauliques pour décharger les wagons dans les bateaux.	Hydraulische Hebekipper zum Entladen von Waggons in die Schiffe.	Hydraulic coal-tip for unloading waggons into boats.
Prise d'eau pour la locomotive.	Speisepumpe für Lokomotiven.	Locomotive feeding-pump.

Mines de Marles.	**Gruben von Marles.**	**Marle Mines.**
Indicateur de direction.	Richtungszeiger.	Direction indicater.
Voies de garage.	Parkirungsgeleise.	Sidings.
Voies de service.	Durchgehende Geleise.	Railroads.
Traversée.	Kreuzung.	Crossing.
Voie d'arrivée des wagons chargés.	Ankunftsgeleis für beladene Waggons.	Line where loaded waggons arrive.

Remise pour les travaux.	Arbeitsschuppen.	Work shop.
Voie de la vente à la campagne.	Geleis für den Verkauf nach dem flachen Lande.	Line for country sale.
Concierge.	Pförtner.	Porter.
Surveillant.	Aufseher.	Care-taker.
Entrée des voitures.	Einfahrt für Wagen.	Waggon entrance.
Voies des bois.	Geleise für Holztransporte.	Timber line.
PLANCHE II.	BLATT II.	PLATE II.
Mines de Noeux.	**Gruben von Noeux.**	**Noeux Mines.**
Coupe transversale.	Querschnitt.	Transverse section.
Bateau en chargement.	Fahrzeug in Ladung.	Boat loading.
Mouvement de manoeuvre de la trémie.	Bewegung des Ladetrichters.	Movement of the funnel.
Contrepoids équilibrant.	Gegengewicht.	Counter-balancing weight.
Bec mobile.	Bewegliches Endstück.	Moveable end of funnel.
Wagon en déchargement.	Zu entladender Waggon.	Waggon unloading.
Grue opérant le basculement des caisses des wagons.	Krahn zum Kippen der Waggonkasten.	Crane tipping the waggons.
Mines de Courrières.	**Gruben von Courrières.**	**Courrières Mines.**
Vide et plein.	Leer und beladen.	Empty and full.
Trappe mobile.	Fallthür.	Trap-door.
Mouvement de commande.	Führung.	Leading.
Passerelle.	Laufbrücke.	Foot-bridge.
Treuil de halage.	Zugwinde.	Windlass.
Chaudière.	Dampfkessel.	Boiler.
Appareil de touage du bateau.	Schiffszugapparat.	Fixed cable.
(Pour les autres inscriptions, voir les traductions sous „Mines de Noeux".)	(Die Uebersetzung der sonstigen Inschriften findet man unter „Gruben von Noeux").	(For other descriptions, see the translations under „Noeux Mines").
Mines de Liévin.	**Gruben von Liévin.**	**Lievin Mines.**
Axe de la voie.	Achse des Geleises.	Main line.
Mobile.	Beweglich.	Moveable.
Fixe.	Fest.	Fixed.
Surface de chauffe.	Heizfläche.	Heating surface.
Bornes à pivot.	Zapfenklötze.	Pivot guiders.
Cylindres élévateurs.	Hubcylinder.	Elevating cylinders.
Crochets de soulèvement.	Haken zum Heben.	Lifting hooks.
Bache d'alimentation.	Wasserkasten.	Feeding tank.
Pour les autres inscriptions voir les traductions sous „Mines de Noeux").	(Die Uebersetzung der übrigen Inschriften findet man unter „Gruben von Noeux").	(For other descriptions, see translations under „Noeux Mines").
PLANCHE III.	BLATT III.	PLATE III.
Mines de Lens.	**Gruben von Lens.**	**Lens Mines.**
Elévation parallèle.	Parallelschnitt.	Parallel elevation.
Anneau.	Ring.	Ring.
Piton.	Zapfen.	Ringbolt.
Vanne.	Schütze.	Flood-gate.
Cylindre de basculement.	Cylinder zum Kippen.	Cylinder of coal-tip.
Coupe transversale suivant l'axe d'une glissière.	Querschnitt in der Achse einer Gleitbahn.	Transverse section at end of funnel.
(Pour les autres inscriptions, voir les traductions „Planche II".)	(Die übrigen Inschriften findet man übersetzt unter „Blatt II")	(For other discriptions see translations under Plate II).
PLANCHE IV.	BLATT IV.	PLATE IV.
Mines de Béthune.	**Gruben von Béthune.**	**Bethune Mines.**
Basculeur à pendule différentiel.	Kippapparat mit Differential-Pendel.	Coal-tip with differential pendulum
Vue de face.	Vorderansicht.	Front view.

Charbonnages d'Annezin.	**Kohlenbergwerke von Annezin.**	**Annezin Collieries.**
Chargement des charbons mélangés.	Verladung gemischter Kohlen.	Loading of mixed coals.
Vanne de la trémie.	Schütze des Ladetrichters.	Funnel door.
Noria.	Becherwerk.	Elevator.
Câble sans fin.	Kabel ohne Ende.	Continuous cable.
Coins de calage latéral du wagon.	Seitliche Hemmkeile, welche den Waggon halten.	Wedge to stop waggons.
Contrepoids différentiels.	Differential-Gegengewichte.	Differential counter-balancing weights.

PLANCHE V.	BLATT V.	PLATE V.
Trafic moyen.	Durchschnittlicher Verkehr.	Average traffic.
Débarquements.	Ausschiffungen.	Unloading of
Houilles. sur wagon avec les grues.	Kohlen. mittels Krahnen auf Waggons.	Coals. into waggons by means of cranes.
à terre avec les grues.	„ „ „ das Ufer.	on shore „ „ „ „
„ „ à la brouette.	„ Karren „ „ „	„ „ „ „ „ wheel barrows.
Castine.	Kalkstein.	Limestone flux.
Pyrites.	Kies.	Pyrites.
Fontes.	Gusseisen.	Cast-iron.
Ferrailles.	Alt Eisen.	Old iron.
Scories.	Schlacken.	Slag.
A terre par wagon avec les grues.	Mit Krahnen auf Waggons und dann auf das Gelände.	Ashore in waggons by means of cranes.
Fers et tôles mis à terre à bras et repris pour être chargés sur bateau à bras ou avec les grues.	Eisen und Bleche mit der Hand auf das Ufer gebracht, von da mit der Hand oder mit Krahnen in Schiffe verladen.	Iron and sheet iron put ashore by hand and removed to be loaded on board boats by hand or by means of cranes.
Grosses pièces chargées avec la grande grue.	Grosse Stücke, verladen vermittelst des grossen Krahnes.	Large objects loaded by the large crane.
Anthracite prise au wagon et embarquée à la brouette.	Anthracitkohlen, vom Waggon entnommen und mit Karren eingeschifft.	Anthracite coal taken in waggonloads and shipped by means of wheel-barrows.
Appareil de levage	Hebeapparat.	Lifting apparatus.
Prise d'eau.	Speisepumpe.	Feeding pump.
Corps de garde.	Wächterhaus.	Watch.
Gardien du port.	Hafenwächter.	Harbour watchman.
Voie des grues roulantes.	Laufkrahngeleis.	Rails for moveable cranes.
Fosse de chargement des wagons.	Lagerplatz für Beladung der Waggons.	Place for loading waggons.
Rigole.	Wassergraben.	Trench.
Terre.	Erde.	Earth.
Escarbilles.	Gestübbe.	Cinders.
Etang.	Teich.	Pond.

PLANCHE VI.	BLATT VI.	PLATE VI.
Mines de Blanzy.	**Gruben von Blanzy.**	**Blanzy Mines.**
Ateliers de lavage et criblages.	Arbeitsplätze zum Waschen und Sieben.	Washing and sifting yards.
Estacade.	Ladegerüst.	Raised platform or scaffolding.
Vente au détail.	Kleinverkauf.	Retail sale.
Grue pour le chargement du coke.	Krahn zum Verladen von Kokes.	Crane for the loading of coke.
Brai.	Pech.	Pitch.
Estacades pour le chargement direct au moyen de wagonnets.	Ladegerüste für die directe Verladung mit kleinen Waggons.	Platform for direct loading of by means of small waggons.
Garage.	Liegeplatz.	Sidings.
Port des Papeteries d'Essonne.	**Hafen der Papierfabrik von Essonne.**	**Port of the Paper Works of Essone.**
Voie des grues.	Krahngeleis.	Rails for cranes.
Réfectoire.	Speisehalle.	Dining room.
Galerie filtrante souterraine.	Unterirdischer Filtrirgang.	Subterranean filter bed.

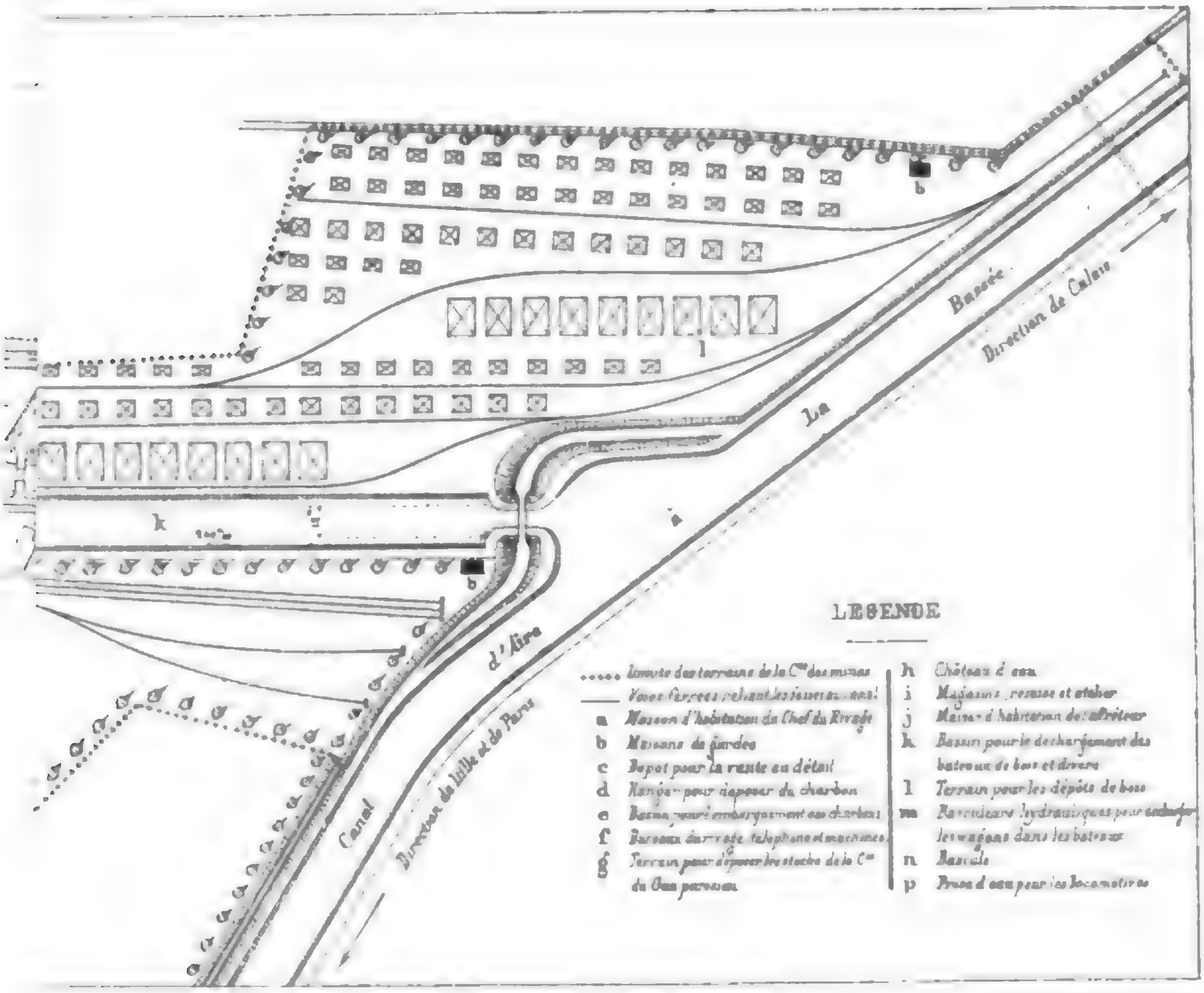
Résine.	Harz.	Resin.
Bassin souterrain et puisage.	Unterirdisches Becken und Schöpfstelle.	Subterranean basin and drainage.
Chaudières et pompes.	Kessel und Pumpen.	Boilers and pumps.
Coupe en travers du port suivant l'axe d'une grue.	Querschnitt des Hafens in der Achse eines Krahnes.	Cross section of the port following the line travelled by a crane.
Port des Forges et Laminoirs de Marnaval.	**Hafen der Hütten- und Walzwerke von Marnaval.**	**Port of the iron Works and Rolling Mills of Marnaval.**
Raccordement.	Anschlussgeleis.	Junction.
Chemin de halage.	Leinpfad.	Tow-path.
Pont levis.	Aufziehbrücke.	Draw-bridge.
Quai en maçonnerie.	Gemauerter Kai.	Quay of masonry.
Matières premières.	Rohstoffe.	Raw materials.
Voie souterraine.	Unterirdisches Geleis.	Subterranean way.
Voie de reprise de	Geleis zum Wiederaufladen von	Line for reloading of . . . .
Trappes.	Fallthüren.	Trap-door.
Pont tournant en construction.	In Bau befindliche Drehbrücke.	Swinging bridge in course of construction.
Fontes.	Gusseisen.	Cast iron.
Elévation de côté.	Seitenansicht.	Elevation of the side.
„ „ face	Vorderansicht.	„ „ „ front.
Culbuteurs des estacades à trémies.	Kippapparate der Ladegerüste mit Gleitbahnen.	Tilting apparatus of the platforms upon which are the funnels.
Trafic du port.	Hafenverkehr.	Traffic of the port.
Expéditions.	Versandt.	Sailings.
Arrivages.	Angekommene Güter.	Arrivals.
Ports de Nancy.	**Häfen von Nancy.**	**Ports of Nancy.**
Rue particulière.	Privatstrasse.	Private street.
Bureau de navigation et pontier.	Schifffahrtsbureau und Brückenwärter.	Shipping office and bridge keeper.
Commerce.	Handel	Trade.
Bois et combustibles.	Holz und Brennstoffe.	Timber and combustibles.
Bois de construction.	Bauholz.	Building timber.
Pont roulant.	Rollbrücke.	Rolling bridge.
„ flottant.	Schwimmende Brücke.	Floating bridge.
Grue sur estacade.	Krahn auf Ladegerüst.	Crane on platform.
Grue mobile, pivotante et roulante sur rails.	Auf Schienen laufender Drehkrahn.	Moveable crane, turning and rolling on rails.
Usine à Gaz.	Gasanstalt.	Gas works.
Bassin particulier.	Privatbecken.	Private dock.
Pierres de taille.	Hausteine.	Cut stone.
Pour les fûts de vin.	Für Weinfässer.	For wine-casks.
Port de Neuves-Maisons.	**Hafen von Neuves-Maisons.**	**Port of Neuves-Maisons.**
Chemin de fer industriel.	Industriebahn.	Goods line.
Raccordement.	Anschlussgeleis.	Junction.
Voie de . . . . m.	Spurweite . . . . m.	Line . . . . m.
Appareil de chargement des minerais.	Apparat zum Verladen von Mineralien.	Apparatus for loading ores.
Hauts fourneaux.	Hochöfen.	Blast furnaces.
Voie de service.	Durchgehendes Geleis.	Railway lines.
Fonderie.	Giesserei.	Foundry.
Dépôt de crasses.	Schlackenlager.	Rubbish heap.
Ciment de laitier.	Schlackencement.	Slag cement.
Jetée.	Landungsbrücke.	Pier.
Voie de la grue roulante.	Laufkrahngeleis.	Line of the rolling crane.
Prise d'eau.	Speisepumpe.	Feeding pump.
Branche sud.	Südlicher Arm.	Southern branch.
Ancienne ballastière.	Ehemalige Kiesgrube.	Old gravel-pit.
Pour les autres inscriptions, voir les traductions sous „Planche II").	(Die Uebersetzung der übrigen Inschriften findet man unter „Blatt II").	(For other descriptions see translation under „Plate II").

Mines de Bruay.	**Gruben von Bruay.**	**Bruay Mines.**
Basculeur hydraulique.	Hydraulischer Kippapparat.	Hydraulic coal-tip.
Mouvement de commande de la porte de la trémie.	Führung der Ladetrichterthür.	Manner of regulating the door of the funnel.
Tablier mobile articulé placé entre le wagon et la trémie.	Bewegliches, gegliedertes, zwischen dem Waggon und dem Ladetrichter liegendes Schutzblech.	Moveable linked platform placed between the waggon and the funnel.
Taquets de calage.	Schutzklampen.	Butts for stopping waggons.
PLANCHE VII.	BLATT VII.	PLATE VII.
Détails de l'outillage.	Nähere Darstellung der Ausrüstung.	Particulars respecting the plant.
Couloir mobile.	Bewegliche Lauftreppe.	Moveable gangway.
Coupe sur l'axe de l'appareil et sur la trémie longitudinale.	Schnitt in der Achse des Apparates und Längsschnitt des Ladetrichters.	Section through the middle of the apparatus, longitutinally through the funnel.
Vue de face.	Vorderansicht.	Front view.
Coupe de l'estacade, la trémie longitudinale enlevée.	Durchschnitt des Ladegerüstes nach Entfernung des Ladetrichters.	Section of platform (or scaffolding), the funnel removed.
Estacades de chargements en bateaux des houilles criblées.	Ladegerüste zum Verladen von gesiebten Kohlen in Schiffe.	Platforms for loading boats with sifted coals.
Trémie de chargement direct sur le pont du bassin.	Ladetrichter zum directen Verladen von der Hafenbrücke aus.	Funnel for loading direct upon the bridge of the dock.
Wagon servant aux embarquements par les trémies du pont et de la grande estacade.	Waggon, welcher zur Verschiffung mittels der Ladetrichter auf der Brücke und auf dem grossen Ladegerüste dient.	Waggon for the use of vessels with the aid of funnels of the bridge and large platform.
PLANCHE VIII.	BLATT VIII.	PLATE VIII.
Port particulier de l'Usine Solvay.	Privathafen der Fabrik Solvay.	Private Port of the Solvay works.
Fig. 1. Coupe de la grande passerelle au droit d'une grue.	**Fig.** 1. Querschnitt der grossen Laufbrücke bei einem Krahne.	**Fig.** 1. Section of the large bridge in front of a crane.
Fig. 2. Appareil funiculaire pour le déchargement des houilles.	**Fig.** 2. Seilbahnapparat zum Ausladen von Kohlen.	**Fig.** 2. Funnicular apparatus for the unloading of coals.
Cabine de manoeuvre.	Steuerungshütte.	Workman's box.
Passerelle de protection.	Schutzbrücke.	Protection bridge.
Dépôt de houilles.	Kohlenlager.	Stock of coal.
Fig. 3. Grande passerelle par dessus la route et le canal.	**Fig.** 3. Grosse Laufbrücke über der Chaussée und dem Kanale.	**Fig** 3. Large bridge over the road and the canal.
Elévateur hydraulique.	Hydraulischer Aufzug	Hydraulic elevator.
Fig. 4. Calcaires.	**Fig.** 4. Kalkstein.	**Fig.** 4. Limstone.
Fig. 5. Elévation générale de la grande estacade.	**Fig.** 5. Längsschnitt des grossen Ladegerüstes.	**Fig.** 5 General view of the large platform.
Fig. 6. Elévation d'une travée.	**Fig.** 6. Längsschnitt eines Joches.	**Fig.** 6. Elevation of an arch.
Plan (de l'Usine de Solvay).	**Plan** (der Fabrik Solvay).	**Projection** (of the Works of Solvay).
Propriétés diverses.	Verschiedene Besitzungen.	Various properties.
Atelier de concassage.	Stampfwerk.	Crushing works.
Calcaire.	Kalkstein.	Lime stone.
Fabrication de la chaux.	Kalkfabrikation.	Manufacture of lime.
Passerelle publique pour piétons.	Oeffentliche Fussgängerbrücke.	Public foot-bridge.
Appareil funiculaire.	Seilbahn.	Funnicular apparatus.
Cabine.	Hütte.	Cabin.
Soudière.	Sodafabrik.	Soda factory.
Générateur.	Generator.	Generator.
Terre-plein.	Ufergelände (Erddamm).	Earthen dam

Inscriptions souvent répétées.	*Häufig vorkommende Inschriften.*	*Words frequently repeated.*
Basculeur.	Kippapparat (Hebekipper).	Coal-tip.
Briquettes.	Presskohlen.	Briquettes.
Charbons.	Kohlen.	Coals.
Chemin communal.	Gemeindeweg.	Road built by the corporation.
Chemin de halage.	Leinpfad.	Tow-path.
„ „ contre-halage.	Stromaufwärts führender Leinpfad.	Counter tow-path.
Contrepoids.	Gegengewicht.	Counter-balancing weight.
Coupe transversale.	Querschnitt.	Transverse section.
Crible.	Sortirsieb, Siebwerk.	Sorting apparatus.
Dépôt.	Lager.	Stores.
Echelle.	Maasstab.	Scale.
Ecluse.	Schleuse.	Lock (or sluice).
Elévateur hydraulique.	Hydraulischer Aufzug.	Hydraulic elevator.
Fosse.	Grube.	Pit.
Garde-barrière.	Bahnwärter.	Keeper.
Grue.	Krahn.	Crane.
Quai d'embarquement.	Einschiffungskai.	Shipping wharf.
Raccordement.	Anschluss (Eisenbahn-).	Junction.
Route nationale.	Heerstrasse (Landstrasse).	Road built by the state.
Sable.	Sand.	Sand.
Trémie.	Ladetrichter.	Funnel for lading purposes.
Treuil.	Winde.	Windlass.

Calais).

Pl. I.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Bassée
Direction de Calais
Direction de Lille et de Paris
LEGENDE
Limite des terrains de la Cie des mines
Voies ferrées reliant les fosses au canal
a Maison d'habitation du Chef du Rivage
b Maisons de gardes
c Dépot pour la vente en détail
d Rangs pour déposer du charbon
e Bassins pour l'embarquement des charbons
f Bureaux du rivage, téléphone et machines
g Terrain pour déposer les stocks de la Cie du Gaz parisien
h Château d'eau
i Magasins, remise et atelier
j Maison d'habitation de l'affréteur
k Bassin pour le déchargement des bateaux de bois et divers
l Terrain pour les dépôts de bois
m Basculeurs hydrauliques pour décharger les wagons dans les bateaux
n Bascule
p Prise d'eau pour les locomotives

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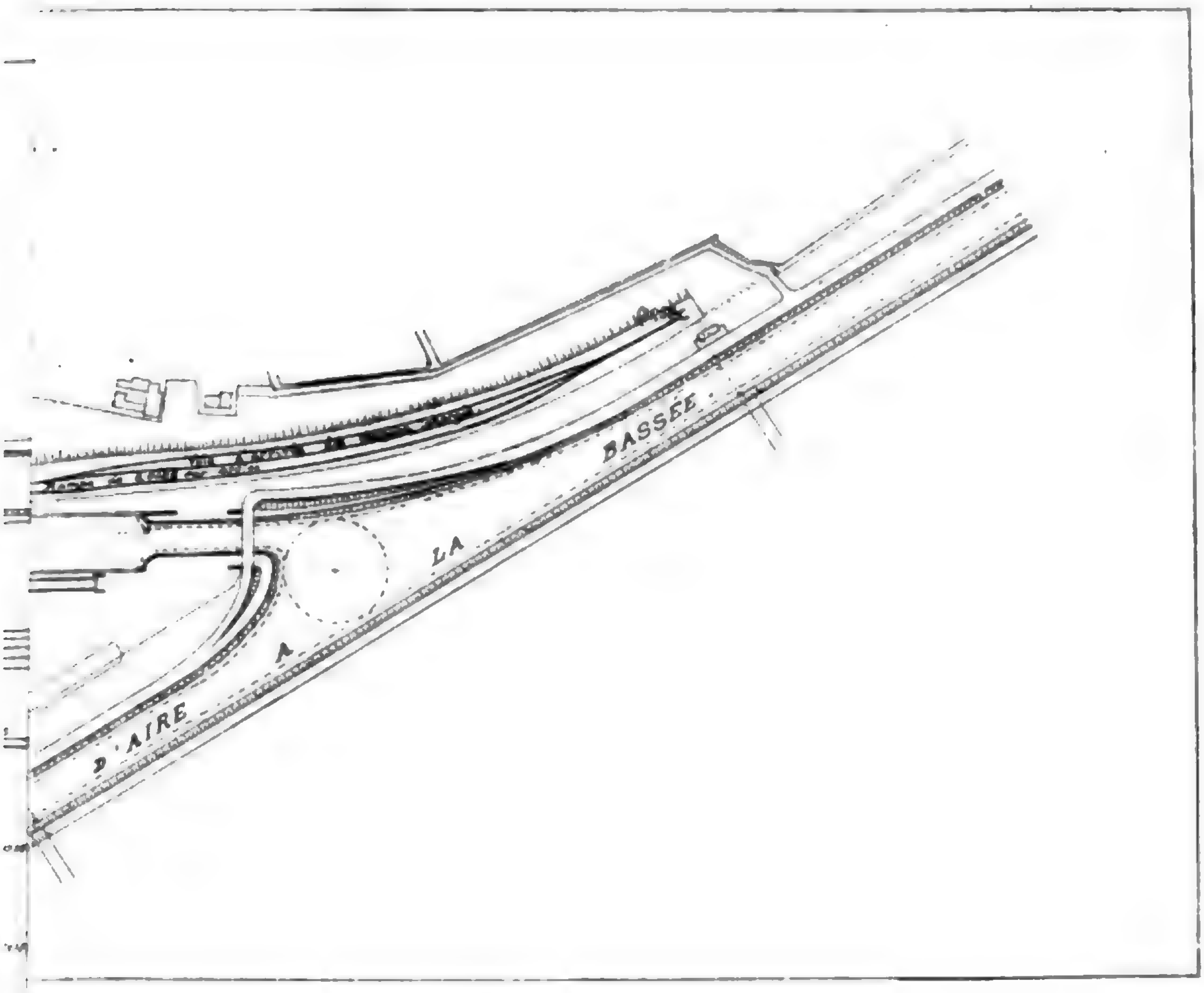
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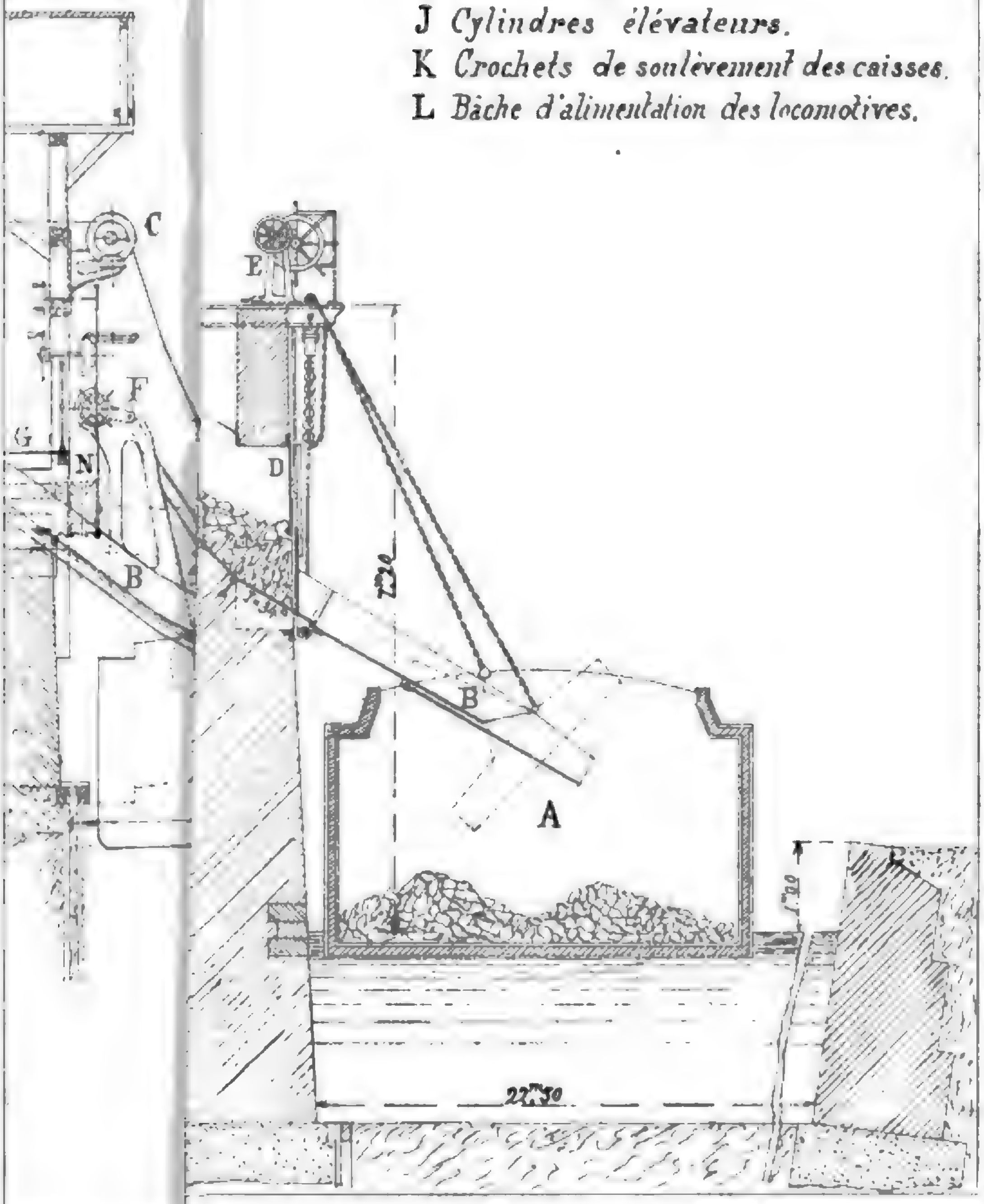
Pl. 11.

LEGENDE

- A *Bateau en chargement.*
- B *Trémie mobile.*
- C *Trémie fixe.*
- D *Vanne.*
- E *Treuil de manœuvre de la Trémie et de la vanne.*
- F *Wagon en déchargement.*
- G *Chaudière de 14^{m} de surf^{ce} de chauffe.*
- H *Treuil de halage des wagons.*
- I *Bornes à pivot.*
- J *Cylindres élévateurs.*
- K *Crochets de soulèvement des caisses.*
- L *Bâche d'alimentation des locomotives.*



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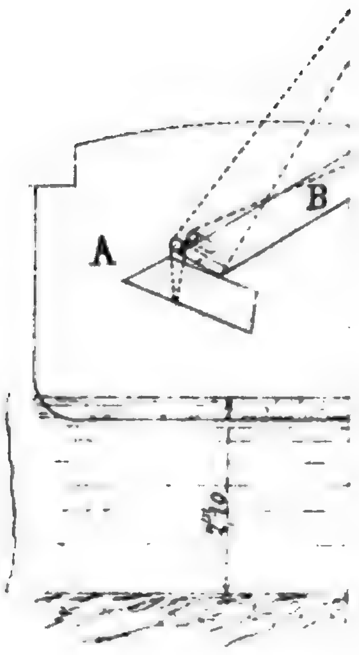

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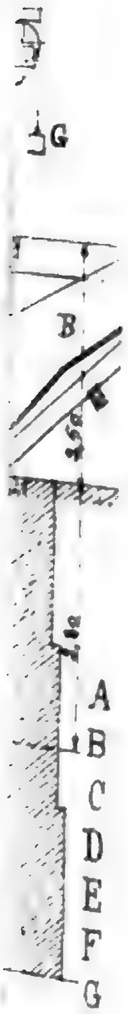

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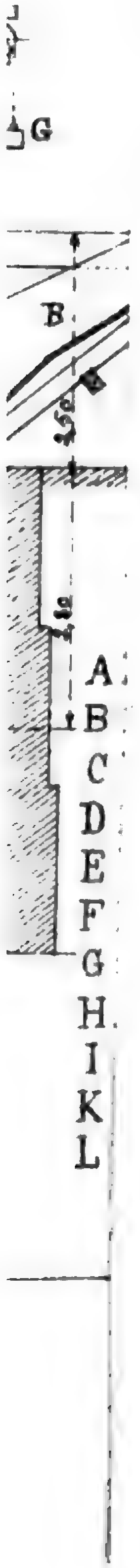

Port de Bois Bretoux.

Trafic moyen du port de 1885 à 1892.

Débarquements.			Embarquements.		
	Tonnage	Prix de la Tonne		Tonnage	Prix de la Tonne
	[illegible]	[illegible]	Fers et tôles mis à		

LÉGENDE

A *Grue de 1600*^{K}.
B ——— *2500*^{K}.
C ——— *6000*^{K}.
D *Appareil de levage de 50 tonnes.*

a *Prise d'eau.*
b *Bureaux.*
c *Corps de garde.*
d *Machine électrique.*

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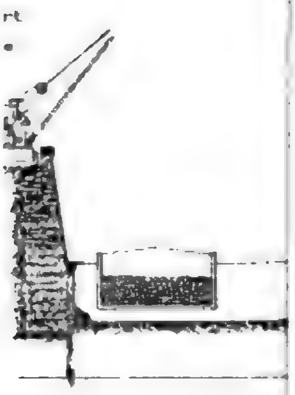
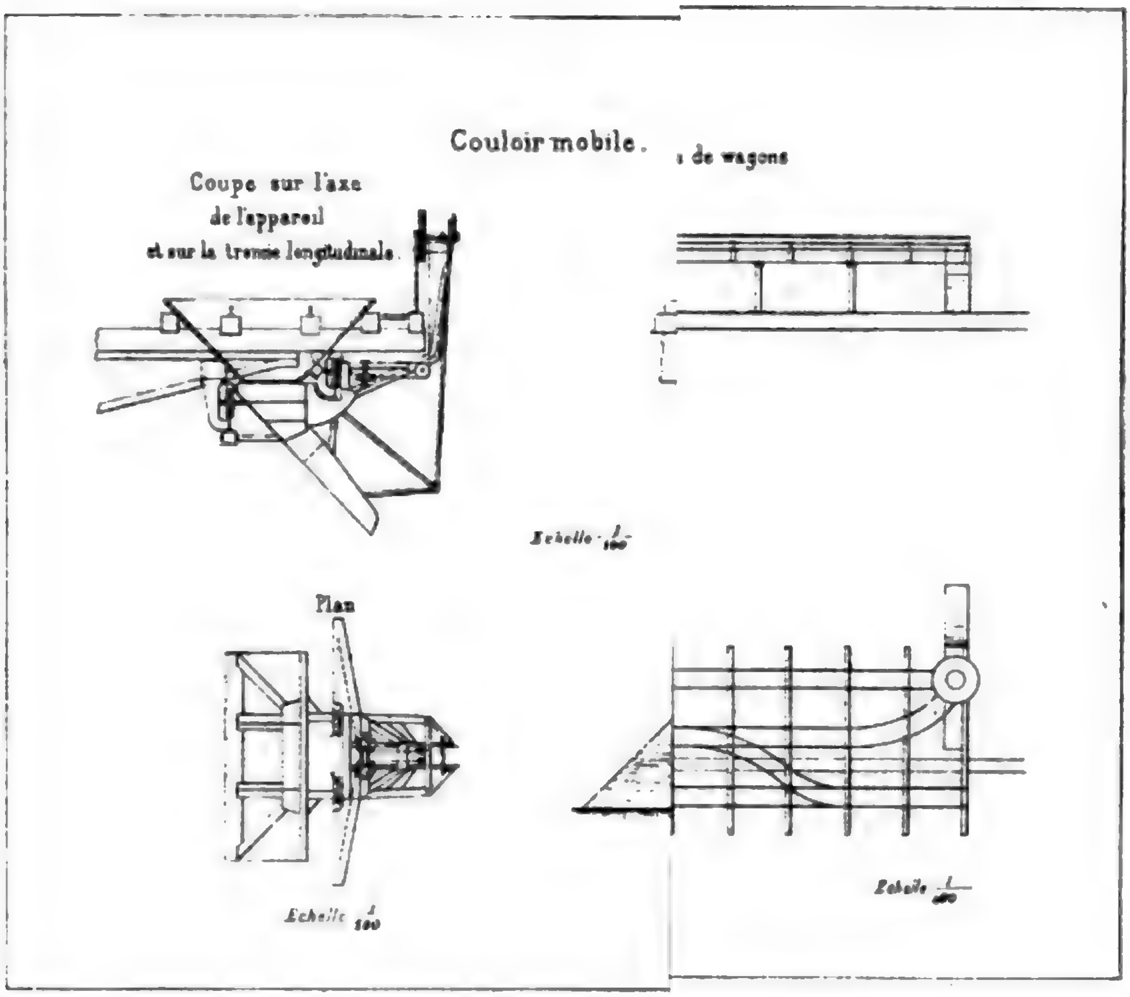


fic du port de Marneval
de 1886 à 1893

éditions	Arrivages	Tonnage total
725[1]	171 636[1]	186 131[1]
3 681	166 466	196 166
220	148 167	178 407
682	138 285	166 961
806	113 851	218 635
218	186 592	216 810
996	200 426	252 168
206	190 226	252 636
926	196 016	263 960

Pl VII.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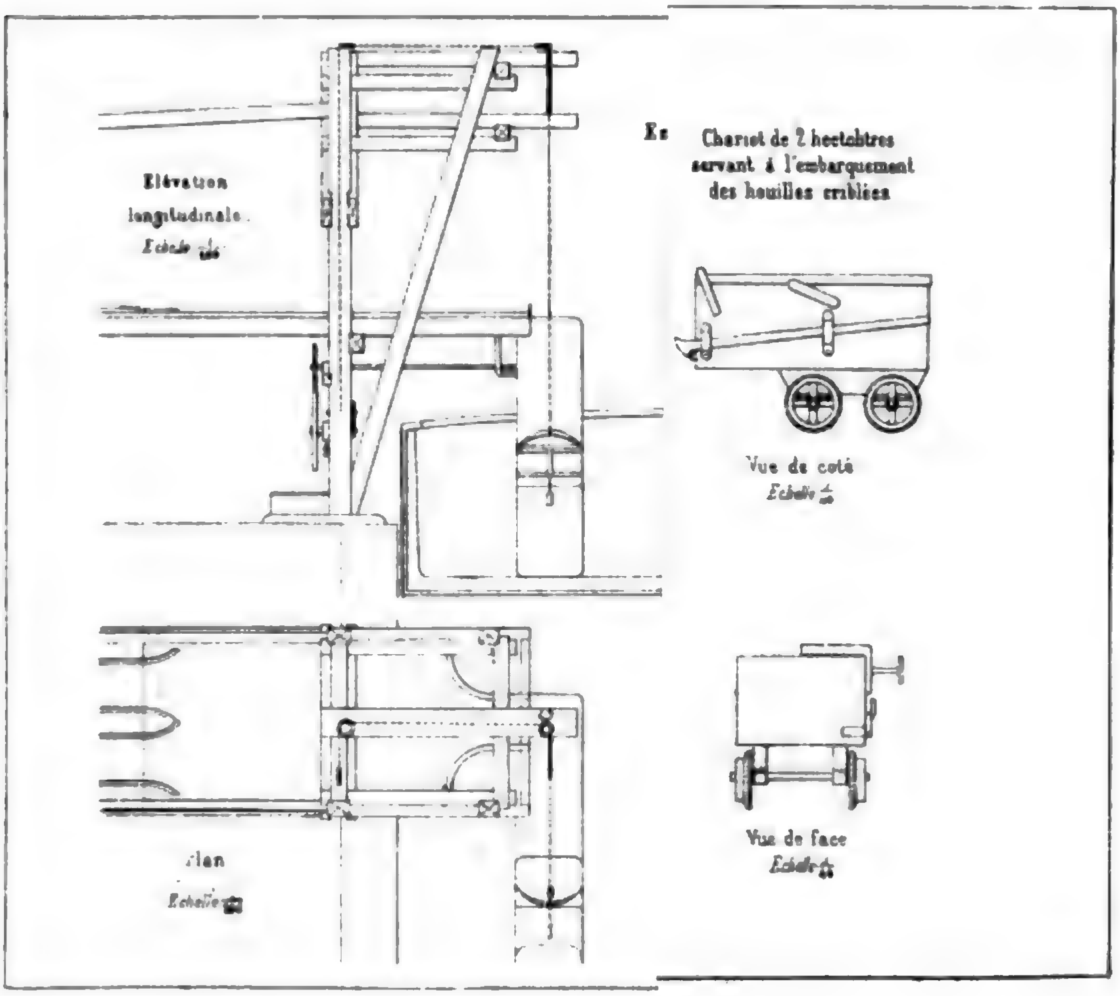
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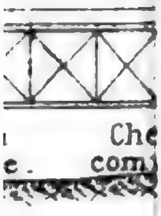

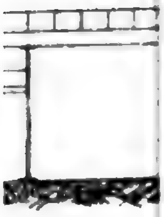

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VIth INTERNATIONAL INLAND NAVIGATION CONGRESS
THE HAGUE 1894.

2th QUESTION.

THE PORT OF ROTTERDAM

BY

G. J. DE JONGH
Director of Public Works, Rotterdam.

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The aspect alone of the different ports of Europe is sufficient to show to the observer, in a most striking manner, the difference between the systems which have been followed in their construction. In one the extent of the ground, in another that of the water, has the greater preponderance; the connection between the space enclosed and that left open along the quays is not in every case the same; the plant for loading and unloading is more or less important; the method of communicating with railways is not everywhere identical, and so forth.

The old ports which have a history are especially remarkable in this respect. Some there are that have been founded in a manner absolutely primitive. and which, nevertheless, have acquired and preserved considerable importance. Others, on the contrary, endowed with the advantages of the most modern construction, only languish in the saddest manner.

What in some ports is considered as of the highest importance, in others is neglected as an insignificant factor.

Those who have the management of the one or the other can nevertheless take the interest of both to heart. To judge fairly of the different systems of construction and working of every maritime port, it is necessary to know both the history and the nature of its activity. This knowledge should be dwelt upon, if there is any question of forming a just estimate of practical consequences and of determining what modifications and what improvements the imitation of existing works is able by analogy of circumstances to inspire. The results obtained in the working of ports are more instructive than the most learned books or treatises, provided however that the circumstances, in which they are obtained, are duly taken into account.

It is for this reason, that in a few short pages we shall endeavour to give a brief account of the port of Rotterdam, its history, the nature of its activity, the details of its construction, its advantages and what it leaves to be desired.

THE PORT OF ROTTERDAM.

It is to their geographical situation that the Netherlands principally owe the development and prosperity of their commerce and navigation Situated between the countries bordering on the Baltic and those of Southern Europe and at the mouth of a river which penetrates to the very heart of this continent, they were in the Middle Ages the most important market.

Bruges, Ghent, Antwerp, were at that time the great meeting places for merchants from all countries. Spanish and Portuguese ships brought to these cities the varied merchandise of the South of Europe and the Indies, which had reached the Mediteranean by way of Alexandria and Constantinople, and the products of Russia and the countries of the north found their way thither by the navigation of the Baltic, as well as, by the Rhine and Moselle, the wines of Germany and the timber of its forests. There also flowed in the produce of the Flemish industries, among which woollens and cloth had a large place.

The southern portion of the Netherlands was at the head of the movement, but the north also profited from this prosperity. Neither Bruges nor Antwerp themselves took any important part in the shipping movement of their ports. This movement belonged to foreign countries and to towns in the North of the country. The latter were soon able even to make sure of taking the lead.

Originally the navigation was confined to sea fishing for local consumption. Rotterdam at first was but a fishing village. The discovery of the art of salting and packing herrings in barrels, which rendered this fish an article of exportation to a distance, opened a new era for the Netherlands. The fishermen began themselves to carry their takings to every market in exchange for foreign commodities and themselves to seek the salt that they required in the ports of Brouage et la Rochelle, of Santa Maria and San Lucar.

In 1475, Hoorn and Enkhuisen alone had a fleet of seventy craft at sea loaded with salt. Herring fishing became in every respect a gold mine for our country.

In 1562, the number of boats called *buses*, which were engaged in this trade was estimated to be seven hundred, of which six hundred belonged to Holland and one hundred to Zealand. Side by side with the fishing fleet, the fleet of merchant vessels also developed to the same degree. That of the province of Holland comprised, according to the estimate of that time, from eight hundred to a thousand sea-going vessels. Amsterdam sometimes had in the roads five hundred large vessels, nearly all of them Dutch.

The Dutch had acquired pre-eminence at sea. The prosperity of their country had therefore grown considerably and become more generalised. Such was the state of things when, in 1568, the rising of Lesser Holland broke out against the power of Spain. Victory came from the sea. With the help of their powerful fleets, the Northern Netherlands succeeded in driving the Spaniard from their territory. The Southern Netherlands which, as we have seen, had not the same resources at their disposal, were unable to meet with the same success and doubly suffered the desasters of the war. In the space of but a few years the Flemish cities of Bruges and Antwerp, then in most flourishing condition, declined completely. Commerce and industry betook itself entirely to the towns of Holland. The depopulation was carried to such an extent, that at Antwerp a considerable number of houses remained empty, and people were obliged to pay others to live in them to take care of them.

While the „Beggars” (Geuzen) blocked the Flemish ports, they at the same time succeeded in keeping the sea open for themselves. It is a remarkable fact that, in spite of the hostilities, for several years the trade of the Netherlands was regularly maintained in the Spanish and Portuguese ports, and we see the Dutch traders taking thither, not only their grain and timber, but even munitions of war.

The impetus taken by our trade and navigation already excited the envy of England. From the mouth of Englishmen Queen Elizabeth had to submit to hear it stated that the two provinces of Holland and Zealand alone possessed more vessels and seamen than the whole of the Kingdom of the British Isles. There were therefore no obstacles to the increase of the trade and navigation of the Netherlands, nothing could arrest their development.

Philip II also, it will readily be understood, was obliged to seek the means of dealing his rebellious subjects a fatal blow. This he fancied he could do by twice, in 1584 and in 1594, ordering the seizure of the Dutch vessels in the ports of Spain and Portugal. The town of Hoorn alone thus lost thirty vessels in 1584. But this measure was especially unfortunate for Spain herself. Prevented from buying the produce of India in the markets of Spain and Portugal, the Dutch resolved themselves to go in search of it in the lands of its production, and thus they laid the foundations in the East Indies of the opulent colonial empire, which still to a large extent belongs to Holland. This trade with the Indies rapidly extended. The East India Company was founded and, during the twelve years' truce, from 1600 to 1621, already possessed four hundred large ships with crews to the number of five thousand men.

For the first few years it paid an averege dividend of 35 %, and its chiefs estimated that twenty thousand persons were interested in it.

Fishing and the intercourse by sea with the ports of Europe and all matters relating thereto, were none the less the principal sources of prosperity.

In 1601 herring fishing occupied fifteen hundred Dutch and Zealand *buses*. Delfshaven furnished two hundred as its share. Twenty thousand sailors were engaged in this fishing industry, and forty thousand other persons lived upon it, in the ship yards, where the *buses* were built, repaired and fitted out.

In 1598, in a single week, six hundred vessels brought their cargoes of wheat from the coasts of the Baltic to Amsterdam. In 1601, in the space of three days, from eight to nine hundred craft set sail from this port for the Baltic to fetch cargoes of corn. Ship-building occupied a large population; not less than a thousand sea-going vessels of different tonnage were launched annually and at least as many for the inland navigation.

What a spectacle the small country of Holland presented to Europe at the beginning of the 17th century. A narrow strip of land, with difficulty rescued from the ocean by its dams and hydraulic draining apparatus, makes war upon the formidable potentate who disposes of the treasures of both Indies; a zeal, courage and activity of its own furnish it with the means to make war, and this war itself becomes a source of prosperity. Holland overflows with every kind of merchandise, which she nevertheless does not produce. She hardly cultivates any cereals and yet no country in Europe has its granaries more richly supplied; she sows no flax, and yet she is engaged largely in weaving; she has no flocks or herds, and still she abounds in woollens and cloths, she has no vineyards, but she is the mart for wines from Germany and France; no forests, and she builds more ships than the rest of the Continent.

This rapid evolution and prosperity should be reflected and is reflected in effect in the history of the Netherland ports.

At the commencement of the rising against Spain, Rotterdam had only a population of 26000 souls.

On the 9th April 1572 it was taken by the Spaniards under the command of Bossu, sacked and inundated with blood, and then occupied till 21st July of the same year.

Its harbour was at that time only the basin which is today known as „kolk".

Rotterdam recovered, however, so rapidly from the disaster of 1572 and became so prosperous that between 1590 and 1620 it was able to establish the following docks: „Oude Haven", „Blaak", „Wijnhaven", „Scheepmakershaven", „Leuvehaven", „Boerengat" and „Buizengat".

Moreover the dimensions of these docks were not without importance, and in that epoc, it was a remarkable thing to design and establish, in so short a time and with the means and implements then at one's disposal, docks 70 metres in width.

The names of Haeringvliet (Herring River) Buizengat (*Buse* channel), Wijnhaven (Wine Harbour), Scheepmakershaven. (Shipbuilders Harbour), still preserve the memory of the powerful elements of the public prosperity. On the south side of the Scheepmakershaven were the shipbuilding yards.

In the 17th century the trade and navigation of the Netherlands reached their apogee. The works of the harbours no longer called for any important extention. At the commencement of the 18th century only the shipbuilding yards were removed to another dock, the Zalmhaven (Salmon Port), to make room on the Boompjes Quay for the inhabitants and principal houses of business.

Only towards the middle of the present century, when steam navigation became established, was it necessary to think of giving a greater development to the works of the port. From 1850 to 1860, the Boompjes were provided with quays of masonry, and the wharfs named Oosterkade, Willemskade and Westerkade were built along the river, altogether presenting a considerable extension of 2170 metres.

At the same time the wharf of the Rhine railroad was built and fitted with wooden bridges for a distance of 500 metres. Two new docks with quays of masonry were also excavated, the Veerhaven and the Westerhaven.

The sandbanks at the mouths of the Meuse, in which there was formerly sufficient depth of water for sea-going vessels to reach Rotterdam, involved the dredging of the Voorne and Putten canal. This work was executed between 1820 and 1827 during the reign of William I. Its achievement rendered Rotterdam accessible, at high water, to vessels drawing not more than 56 decimetres of water. The dimension of the locks however did not admit of the passage of vessels more than 70 metres in length and 14 in width.

In the second half of our century the trade of the world reached its highest development and naval architecture underwent an entire transformation. It became evident that for the ports of Amsterdam and Rotterdam to compete with those of neighbouring countries, it was absolutely necessary to create better water-ways to those two cities.

A law of 1863 decided upon the construction of the canal from the North Sea to Amsterdam and a new mouth to the Meuse by piercing the dunes at the Hook of Holland, what is now known as the new seaway. In 1872, the first ships passed through, although it was still far from complete. At the same time the State executed extensive works in railways, works which connected in every direction the ports and principal towns of Holland with the system of European railroads.

At Rotterdam the State constructed the viaduct which passes through the town, and also the bridge across the Meuse, which is connected with it, and on the southern bank of the stream the dock named Spoorweghaven (Railway Harbour) and the goods station of Feijenoord.

The city dredged the Koningshaven (King's Harbour), built quays of masonry round the island called Noordereiland as well as the south bank of the Koningshaven, and joined the new southern quarter to the ancient portion of the city by a fixed bridge across the Meuse and a swing-bridge across the Koningshaven.

To meet the more extensive movement of trade and navigation, which the opening of the new sea-way and the perfecting of the system of railways seemed to anticipate, a company was formed under the name of the Rotterdamsche Handelsvereeniging (Rotterdam Commercial Company). This company obtained from the town a lease of the lands lying between Spoorweghaven and the street named Rosestraat. The Association there excavated two docks called Binnenhaven and Entrepôthaven, fitted out these docks and the east bank of the Spoorweghaven with quays of masonry erected sheds and ware-houses, furnished the site with sufficient engines for working purposes and everything which the service of a modern port requires, including good connection with the railroads.

The Association expended thirteen thousand florins in this work, which was completed in 1878. The improvement of the river route from Rotterdam to the sea unfortunately did not advance so rapidly as was expected. In 1878 there was still at the mouth only a depth of forty six decimetres at high water.

This *contre-temps*, complicated by certain financial difficulties, obliged the Commercial Association of Rotterdam to go into liquidation in 1879. In 1882 the town took over, for four million florins, all the works established by the Association and since that time carries them on under the name of Commercial Establishments.

The disappointments met with in the improvement of the navigable route from Rotterdam to the sea led to the adoption of a new system of work. One had recourse to dredging on a large scale, avoiding as much as possible the wearing away of the banks by the current, in order to prevent the formation of sand-banks in the sea in front of the new mouth of the river.

In 1882 the enterprise was vigorously taken up and good results soon began to be assured.

The following table compares the depth at various periods. Depth in decimetres at high water:

1875	43	1885	74
1876	43	1886	81
1877	49	1887	82
1878	46	1888	85
1879	58	1889	88
1880	46	1890	93
1881	50	1891	93
1882	57	1892	94
1883	64	1893	98
1884	70		

At the Hook of Holland the difference between high and low water is 1.62 metre.

These results are brilliant. They have progressively developed the commercial and navigation movement, as the following table will show:

YEARS.	Arrivals by sea at Rotterdam.		Shipping movements in the inland waters of the kingdom and with foreign ports by river.	
	Number of vessels.	Tons burden.	Number of vessels.	Tonnage in cubic metres.
1850	1970	393 393	—	—
1855	2297	513 971	—	—
1860	2449	673 839	—	—
1865	2459	653 450	—	—
1870	2987	1 189 670	—	—
1875	3485	1 654 571	—	—
1880	3510	1 728 305	63 542	4 008 188
1881	3673	1 786 386	65 832	4 267 189
1882	3929	2 031 566	68 121	4 600 746
1883	3686	1 981 438	70 127	4 754 723
1884	3768	2 142 617	70 366	4 966 642
1885	3724	2 120 347	73 615	5 110 516
1886	3763	2 202 752	75 834	5 274 097
1887	4155	2 488 369	90 363	6 132 665
1888	4528	2 721 479	91 643	6 398 417
1889	4643	2 809 203	92 872	6 777 025
1890	4535	2 918 425	89 969	6 916 442
1891	4467	3 008 779	93 953	7 486 350
1892	4421	3 129 430	95 347	7 836 249
1893	4770	3 614 654	96 421	8 363 358

These figures show us an increase in the last ten years of 80 % in the tonnage of the maritime shipping, and of 75½ % in the tonnage of the inland shipping.

It will readily be conceived therefore, in spite of the great extension, in 1878, of the works of the port, that fresh enlargements had to be made.

However, before commencing the description of them, it is desirable to give some detailed account of the special nature of the activity of our port.

In past centuries the ports of Holland were especially used as the landing-place of every kind of merchandise, which arrived from every part of the world and remained in them exposed for sale for a more or less lengthy period.

This merchandise was brought principally in Dutch vessels, whose captains often carried on the business either on their own account or that of their employers. After a voyage from the Indies, the vessel lay up and discharged her cargo very much at her ease, and very often it was only after several months that she once more put out to sea. The nature of the cargo and its place of destination were generally kept as secret as possible, especially if it was a question of doing business by means of exchange with the inhabitants of distant countries.

Navigation in distant waters was frequently very profitable. Sometimes it happened that two or three voyages were sufficient to pay for the building of the ship. It was still so in the first half of the present century. In 1811, at the time when HENRI DOEFF performed the functions of leader in commercial matters and governor at Décima, the result of a voyage to Japan was valued at one hundred and twenty thousand florins. The vessels which sailed the Baltic wintered as often as not in their own harbours.

A complete change has taken place in this respect. The impetus given by steam navigation, the ever increasing number of the lines of regular service between the ports of the world, the extension of these lines by the navigation of the rivers and canals, the means of communication with the railroad systems, have drawn producer and consumer nearer together. The great brewers of Germany buy their staves directly in the far West of America, the corn merchants of this country treat directly with the exporters of the Black sea and the Baltic. For certain articles there are also special markets; for wools Liverpool, for leathers Antwerp, for margarine and fat Rotterdam; but the large general ports of former times exist no longer. There is direct trafic between the most distant extremities of the universe. Sea-ports are no more than the junctions, from which the different directions of the movement diverge.

The localities from which the greatest number of these rays start, acquired in many ports the greatest importance. In this network there are three factors: the lines of sea-going ships, the railways and the inland navigation lines. Of the whole the latter assuredly have not the least importance.

After the completion, at least by main lines, of the European system of railways, for the transport of goods, considerable attention has been given to the means of inland navigation. The courses of rivers have been improved, small rivers have been canalised and new canals have been dug — all this has been done on a large scale.

Germany in particular has done much in this direction. River boats twenty four metres by ten go up the Rhine as far as Mannheim and Frankfort. The increase in the navigation of the Rhine, this artery of Europe, has especially been a benefit for the port of Rotterdam. From 1880 to 1893 we see the tonnage of the inland shipping rise from 4008188 to 8363358 cubic metres, and the number of river craft, from

63542 to 96421 per annum. The local shipping movement from the Netherlands by inland waters has also undergone a large development. There is not a village of any importance, which does not every week send its boat for the Monday and Tuesday markets of Rotterdam, there landing its merchandise, whether for consumption on the spot or for re-exportation. On those days from fifteen to sixteen hundred of these boats ordinarily stop at our port. The plan joined to the present pamphlet shows the names of the different localities to whose boats a fixed position is assigned on those days in the docks of Rotterdam. A glance is sufficient to show how the inland shipping has absolutely supplanted the sea shipping in the old docks and how these latter craft no longer find room except along the Meuse and in the docks of the left bank.

The development of the inland navigation has had to be taken into account in the plans for the enlargement of the works of the port.

The sea-going vessels which have to trans-ship their cargo into the boats of the Rhine are not, as far as is possible, moored alongside the quays, but in perfectly free positions, so that they can unload simultaneously on both sides.

For this purpose moorings have been laid down in the Meuse, in front of the town, the number of which has been increased in proportion to the requirements, so that at present twenty vessels can find anchorage. But even this number did not always suffice, and other sites have of necessity had to be provided. There was no more room in the bed of the river, and, besides, the necessity was felt of being able to provide in winter a perfectly safe harbour of refuge for the numerous fleet of boats from the Rhine. These considerations led by force of circumstances to the formation of a system of docks with a draught of water relatively great to the extension of the quays, in the midst of which vessels could make fast to ducdalves in order freely to discharge their cargoes on both sides. These data have determined the special form of the actual Rijnhaven and of the Katendrecht docks. The greatest width of the first reaches and even surpasses four hundred metres.

The works carried out by the former commercial association had to be made to fit in, by means of quay dues, with the hire of apparatus for loading and unloading and sites for the deposit of goods either in ware-houses or in the open air. The harbour dues properly so called have been reserved by the town by the clauses of the lease, and it is for this reason that it has given to the Binnenhaven only the width judged to be absolutely indispensable. This dock should not be used for the transshipment of sea cargoes to the boats of the Rhine. In order to prevent robbery, while reducing as far as possible the expenses of guarding against it, all the ground was surrounded with a wall. This arrangement led to the commission of a great error. The bridges at the mouth of the docks were placed too near to the Koningshaven, in which, when the tide is on the ebb or flow, a strong current is produced. The consequence is that at certain hours vessels of large dimensions only enter the docks with great difficulty. It has been sought to obviate this inconvenience in some degree by means of powerful duedalves etc. The *a b c* of the modern art of building seaports is nothing less than avoiding bridges and locks as much as possible.

In 1885 the works of the construction of the Rijnhaven and the Katendrecht dock were commenced. At the present time from seven to seven and a half metres of water are found at low water and the building of quays of masonry on the north and east sides is in process of completion. To the West of the Katendrecht dock, it is desired to dig two others of the same type, which are indicated in the plan by dots.

Still further to the West, the dock named Dokhaven was established in 1882, where are the three iron floating docks belonging to the town. With regard to the working of these we shall have to return.

Next along the left bank of the Meuse we come to the ground set apart for the storage of petroleum. During the last ten years this land has been considerably extended. In 1884, 248 515 barrels of petroleum were loaded at Rotterdam. In 1893, the quanity loaded was 1 146 000. Four commercial companies now import petroleum to Rotterdam; the German-American Petroleum company and the American Company, which only import refined American petroleum, the Pakhuismeesteren (Storehouse Masters), who deal in American and Russian petroleum, in resin and turpentine, and the firm of Rieth and Company, which only deals in Russian petroleum.

The establishment occupies twelve hundred metres of the bank of the Meuse. The unloading is effected on wooden landing-places in three docks — the Sint-Janshaven, the petroleum harbour and the Kortenoord canal, where the empty boats of the inland navigation canals find refuge when the Meuse is covered with floating ice. The land round the docks has been since 1873 entirely devoted to commercial and shipping purposes. However, in order to admit of the establishment of industry in the places bordering the water and connected with the railroads, the town has for this purpose assigned the quarter on the left bank of the Meuse, to the east of the railroad. We have here the dock named Nassauhaven, dug in 1892 and 1893, on the margin of which persons wishing to establish factories can purchase sites immediately alongside the water. The land set apart for workmen's cottages is also put at their disposal at a moderate price.

We have thus given some idea of the importance of the works of our port. Thought has also been given to the establishment of other docks for sea-going and river vessels on the right bank of the Meuse west of the Park Quay.

Negotiations have been opened with the railway companies to bring about a connection with their lines.

A charge, taken on the gross tonnage, is made on all the sea-going vessels which make use of the docks, moorings or other works etablished by the town for the benefit of the shipping.

The following is the tariff:

I. Steamers.

a.	Measuring 650 cubic metres or less, per cubic metre . .	fl. 0.03
b.	„ more than 650 and less than 1000 cubic metres .	„ 0.035
c.	„ more than 1000 cubic metres.	„ 0.0375

II. Sailing Vessels.

a.	Measuring 600 cubic metres or less, per cubic metre . . .	fl. 0.05
b.	„ from 601 to 700	„ 0.06
c.	„ „ 701 to 800	„ 0.07
d.	„ „ 801 to 900	„ 0.08
e.	„ „ 901 to 1000	„ 0.09
f.	„ „ 1001 to 1100	„ 0.10
g.	„ „ 1101 to 1200	„ 0.11
h.	„ „ 1201 to 1300	„ 0.12
i.	„ „ 1300 to 1400	„ 0.13
k.	„ „ 1400 to 1500	„ 0.14
l.	„ „ 1500 to	„ 0.15

The following is the tariff for river craft and rafts of floating wood:

(1)	Steam boats per cubic m. per journey	fl. 0.02
	Or by yearly subscription, per cubic metre	„ 0.80
(2)	Boats of less than 10 cub. m. ant not employing steam, each entrance	„ 0.10
	Or by yearly subscription	„ 1.00
(3)	Sailing boats of 10 cub. m. and over per cub. m. per entrance	„ 0.02
	Or by yearly subscription per cub. metre	„ 0.40
(4)	Rafts of timber, per beam, pale or mast	„ 0.10

The vessels, for which it is desired to retain a fixed position along the quays, as is the case for the ships of regular lines and for boats which come for the markets, pay in addition the following toll, under the name of quay dues:

a.	sea-going vessels, per metre in length, per year	fl. 25
b.	Other vessels	„ 5
c.	Inland boats, which obtain permission to moor, head to quay, per metre in width, per year	„ 5

We will now pass on to the plant, properly so called, of the docks, under which heading I think I shall be able to include the housing of goods, the machinery for loading and unloading, the forms of the dry docks and the connection with the railroads.

The housing of goods must be regarded from two distinct points of view, according as it is for a long or short space of time. The latter, in my opinion, understands the deposit of the goods in sheds or stores, or in the open ground bordering the docks. The nature of the trade of Amsterdam does not require the presence of sheds on the entire length of the quays. Various goods, minerals, coal, timber etc. do not require covered ware-houses for their temporary storage. The ships which directly unload plant for railroads, such as are frequently seen to load with goods upon the spot, also have no need of these. The building of ware-houses should therefore be reserved for the docks, where the need of them is felt. Along the Binnenhaven no sheds are at present to be seen, except those of the Rio Tinto company, which are used for specimens of copper ore imported by this company, and those which are free storehouses.

The use of the open quays of the commercial Establishment for the deposit of goods is paid in the following manner: per space of twenty five square metres or less, for the first three days, or less than three days, fl. 0.30, for each day or fraction of a day over fl. 0.10.

The dues are not incurred by the goods loaded from a vessel or brought thither to load a vessel, if they are removed within two days.

With regard to the sheds, it will at once be remarked, that there are none along the quays on the right bank, at the Meuse railway station. The history of the creation of our port makes the reason of this sufficiently plain. We will not occupy ourselves with these sheds, nor with those of the Feijenoord station at the Spoorweghaven, because they most particularly concern the railway service. Here there is what must be observed respecting those upon the docks of the left bank.

We have started on the principle that shipping and commerce flourish best where, so far as is possible, entire liberty of action is left to them. No systematic regulations have consequently been imposed and those interested in the subject can take their choice throughout the whole extent of our commercial territory.

If the vessels do not wish to unload on the open quays, they can make use of the sheds numbered from 1 to 6 and of the northern half of shed n°. 7, built by the town on the Spoorweghaven.

They pay according to the space occupied. The following is the tariff: per hundred square metres or less for the first three days or less, fl. 3, and afterwards for each day or fraction of a day over, fl. 1.

The measurement is effected at right angles for the entire space where the goods are deposited, without deducting the spaces left open, and the entire width of the area occupied by the sheds always being regarded as let. Regular lines of ships can rent for long periods the sheds erected by the town, so as to store their cargoes as they arrive.

Thus the southern half of shed no. 7 is let to Messrs. RUYS & Co. for the steam lines to New York and Philadelphia at a rent per annum of fl. 6500.

Sheds 14 and 15 are let to Messrs. WM. H. MÜLLER & Co., for lines to Hull, Aberdeen and Cardiff, with land opening on the Koningshaven, at a rent of fl. 5000.

Shed 26, with land opening on the Koningshaven, is let to the house of

TH. VAN OMMEREN, for a London line of steamers, at a rent of fl. 4500.

Railway companies have themselves hired from the town certain storehouses for the reception of goods: The company for the working of State Railways, shed no. 8, at fl. 5967 per annum; the Dutch Railway Company no. 22, at fl. 16690. The town undertakes to keep these sheds in condition.

The commercial companies, which desire to make their own arrangements, can rent open sites, for a longer or shorter period, and there build as they prefer.

Thus, on the Binnenhaven, the Rio Tinto Company has hired a site, for the sum of fl. 3400, for the landing of the copper ores which it imports.

The Netherland American Steam Navigation Company (New York line), the Rotterdam Lloyd (Java line), the house of VAN ES and VAN OMMEREN (Manchester & Liverpool line), the Blauwhoedenveem (Cape of Good Hope line), the African Commercial Company (Congo line) have also rented open sites on the Wilhelminakade and the Rynhaven, 36 metres wide, at fl. 0.75 the square metre.

All these tenants have also to pay the regulation quay dues, 25 florins the metre in length, for the extent of quay which their permanent moorings occupy.

For the landing of goods that remain a long time, the following establishments are provided for trading purposes:

1) *Free landing-places.* There are two, one named the East India House (Oost-Indisch Huis), on the Boompjes, where formerly the East India Company had its headquarters and stores; the other in the vast warehouses and sheds Nos. 12 and 13 on the dock called Entrepôt-haven. They are managed by the town, but they are nevertheless under the continual supervision of the custom officials.

As many goods subject to entrance dues are here received as those free of duty.

The rent is paid monthly according to a fixed tariff.

With regard to the goods which are deposited here, it is understood that their owners are at liberty to sell or pledge them.

2) *Private free landing-places.* These are especially intended for goods paying heavy duties, such as wines and spirits. They belong to private parties, but are under the supervision of the customs, so that nothing can come in or out without the consent of the latter.

3) *Irrgular landing-places.* These establishments receive goods which pay only small duties, e.g. petroleum and cotton oil, which only pay a duty of fl 0.55 per hundred kilogrammes, tobacco and mineral waters. They are managed by companies or by private individuals and are not required to submit to the incessant supervisions of the customs officials. The latter confine themselves to ascertaining the stock in hand, when they think fit, so as to control the declarations on dutiable goods.

4) *Private landing-places.* These are nearly all large ware-houses, built

and managed by corporations known by the name of „veem", which undertake the warehousing of every class of goods, except those susceptible to high duties, which must be landed in free landing-places. Some of these warehouses are ordinarily intended to serve as irregular landing-places.

Certificates, schedules, which can be sold or pledged, are given for the goods located.

The following are the names of the companies at Rotterdam for this purpose.

Pakhuismeesteren (Storehouse Masters), Blauwhoedenveem („Blue Cap" veem), Vriesseveem (Shiver Veem), Maasveem (Meuse Veem).

5) *The numerous warehouses* situated along the docks of the old town, the property of several merchants, which may be hired by flats or whole warehouses.

For the accommodation of goods therefore for a long period, plenty of liberty and competition will be found at Rotterdam.

It is therefore necessary, when new docks are built, that suitable land and boats may be at the disposal of every person or every association desirous of undertaking any enterprise of this nature.

Besides the landing-places enumerated above, there are also, the following on the left bank of the Meuse, under the management of the town:

(1) Sheds A, B, C & D on the Nassaukade, built by the town and let to the Vriesseveem and Pakhuismeesteren, who work them as their own landing-places.

(2) Sheds 17, 19, 21 and 24 on the Binnenhaven and shed 16 on the Spoorweghaven, also built by the town and let like private warehouses.

(3) An open site, given us by lease by the town, on which a private person has built shed 24 on the Binnenhaven, to be used as a warehouse.

(4) The land included between the Wilhelminakade and the north side of the Rijnhaven, sold to the Vriesseveem, the Blauwhoedenveem and Pakhuismeesteren, which have here valuable and well managed private landing-places.

(5) The land on the east side of the Rijnhaven, nearer the dock and sold at a higher price to the Vriesseveem, which has also put up a private landing place here.

(6) A site on the south side of the Rijnhaven, sold to the American Cotton Oil Company, which has an irregular landing-place and has made it their principal dépôt for the Continent.

(7) The land neighbouring the Katendrecht Harbour, let to some timber merchants, who have here established sheds to serve as a dépôt.

(8) A large extent of land, let on long leases (of from 25 to 35 years), to petroleum companies, for their irregular landing-places and the various buildings dependent on them.

The sale of land has brought in from 15 to 25 florins per square metre and the rent from 30 cents to 1 florin per square metre per annum, on account of the more or less considerable advantages of the situation.

The results of these sales and rents is a factor not without importance so far as it affects the building expenses of the port. The land has even acquired a greater value in consequence of this building. It is therefore very right, that the town, which established it, should derive profit from the venture.

A second important point in the management and working of a port is the plant intended for the loading and unloading of goods.

The cranes are the most important.

On the right bank, at the Meuse station, there are two moveable steam cranes of which the lifting power is a ton and a half, five of two tons, and a hand crane of twenty tons.

This apparatus is under the direction of the railway and we have no details respecting the results of their working.

For public use the town has on the right bank only two fixed cranes, one a hand crane of 10, the other a steam crane of 25 tons.

The first is very old, but still a good machine and is placed in the spot named „de Pont", that is to say at the point joining the Wijnhaven and the Scheepmakershaven.

The second was put up in 1860, on the Willemskade, and cost 29000 florins.

On the right bank sea-going vessels and inland navigation craft unload by means of their own engines, unless they have to handle very heavy weights, in which case they haul themselves within reach of one of the cranes.

The degree to which the latter are made use of varies greatly, as will be seen from the following table showing the working results:

YEARS.	Receipts.	Working Expenses.	Nett Profit.
	Florins.	Florins.	Florins.
1883	3230.005	1042.70	2187.305
1884	2270.905	477.20	1793.705
1885	2243.315	664.46	1778.855
1886	1641.225	947.285	693.945
1887	1826.675	577.78	1249.895
1888	1861.65	652.90	1208.75
1889	2685.71	670.50	2015.21
1890	2650.51	783.58	1866.93
1891	2298.49	589.43	1709.06
1892	1241.495	744.01	497.45

These figuress show that the working of the cranes is indifferently remunerative, but under ordinary conditions it is necessarily so in all places. It is only a necessary adjunct to the works of the port. The price of the hire is estimated according to the weight of goods raised. It is the same as for the cranes on the left bank of the Meuse, concerning which we will also give some details:

Since the erection of works by the commercial Association of Rotterdam, it was first decided to employ steam cranes. Twenty three steam cranes were put up on the Spoorweghaven, viz.: a fixed crane capable of lifting 30,000 kilogrammes, 21 moveable cranes of 1500 kilogrammes power and one of 2500 kilogrammes.

The moveable cranes are of Brown's system and can be moved along the quay ou a special rail.

The sereference given in England to hydraulic lifting engines and the use made of them in various similar establishments on the continent, induced the *Direction*, in 1877, that is to say when the works were almost complete, to adopt this system for the plant on the east side of the Binnenhaven and on the sites for landing-places.

It was established according to the plans of Sir William Armstrong, who also made the contract.

The steam engine which puts water under a pressure of fifty atmospheres is of forty horse power. Originally it moved a fixed crane of 30,000 kilogrammes lifting power, two of 1500 kilogrammes and a capstan of 1000 kilogrammes drawing power, all of these being on the Binnenhaven; afterwards its power was distributed over the sites for landing places to two moveable cranes of 1500 kilogrammes, four windlasses and two capstans. In 1886 two other moveable cranes of 1500 kilogrammes were added and were placed on the sites for landing-places, and a coal-tip of 20,000 kilogrammes lifting power on the Binnenhaven.

In fact for a long time much attention was given to the means to be employed to develope the exportation of German coal through our port. People were convinced of the impossibility of succeeding otherwise than by employing an engine which could take the coal out of the railway waggons and place it directly on board ship. The ordinary crane does not work fast enough for this.

The town decided to run the risk of the attempt and had an hydraulic coal-tip erected by Messrs. Armstrong after a plan furnished by the town itself.

The principle of this apparatus is the following: the waggon loaded with coal is raised on a moveable platform to a maximum height of 9.15 metres and is then tipped sufficiently for the coal to fall of itself down on an inclined plane right into the ship's bunkers. When the circumstances are favorable the apparatus can thus discharge, in an hour, twenty waggons containing 10,000 kilogrammes each.

It is rare however that the work can be carried on at this speed. The necessary manipulation of the coal in the hold always causes delay and determines the rate.

For the first few years the use made of the coal-tip did not correspond to the expectations formed of it.

The following are the quantities of coal or coke, that have passed through the apparatus:

1887	7100 tons.	1891	14857 tons.
1888	4110 »	1892	90562 »
1889	4110 »	1893	113909 »
1890	12950 »		

In 1892 the apparatus worked 255 days and 98 nights. In 1893. 267 days and 142 nights.

Only in 1892 did the apparatus yield adequate returns.

Furthermore, the results are at present as follows: the German railway companies continually increase the size of the waggons used for the carriage of coal or coke The result is the need of increasing the lifting power of the coal-tip and to carry it as far as 25000 kilogrammes. It has been decided to do so. By overloading the accumulator the pressure, under which the water works, has been carried as far as from 50 to 60 atmospheres, and the strength of the apparatus has been proportionately increased.

At the same time a new steam engine of a hundred horsepower has been put up in the pumphouse.

Further, a second coal-tip is now being constructed to meet the increasing requirements of the exportation of coal from our port.

This one will be able to raise a waggon weighing 25000 kilogrammes to a maximum height of 10 metres.

The hire of the moveable steam or hydraulic cranes is as follows:

Per day	10 florins.
Per half day	6 »

The first half day finishes at noon, the second commences at one in the afternoon.

If the crane has to work from noon to one o'clock, there is an additional charge of 2 florins.

Night work is payed at the rate of a florin and a half the hour with a minimum of six florins, unless the night work is the continuation of day work, in which case the minimum is reduced to three florins.

The following is the tariff for fixed cranes:

Articles weighing.	Loading or unloading.	Trans-shipment.
1501 to 5000 kilos, per 1000 kilos	fl. 0.75	fl. 1.15
5001 » 10000 » » » »	» 1.15	» 1.75
10001 » 15000 » » » »	» 1.50	» 2.25
15001 » 20000 » » » »	» 2.25	» 3.00
20001 » 25000 » » » »	» 3.00	» 3.75
25001 » 30000 » » » »	» 4.00	» 5.00

When the loads have to remain some time on the cranes, there is an additional payment, viz.:

Weights of 5000 kilos, per hour	fl. 5
From 5000 to 10000 „ „ „	„ 8
„ 10001 „ 15000 „ „ „ . .	„ 13
„ 15001 „ 20000 „ „ „	„ 20
„ 20001 „ 25000 „ „ „	„ 30
„ 25001 „ 30000 „ „ „	„ 40

Fractions of an hour are counted as whole hours.

For the fixing in position and removal of masts and bowsprits, without shrouds, per centimetre in diameter in the thickest part . . . fl. 0.15
with shrouds . . . „ 0.225

For the fixing in position or removal of masts with stays only, on inland waterboats on the same basis as the above, that is to say per centimetre in diameter. . . . . fl. 0.10

The minimum price for the hire of fixed cranes is ten florins.

When a crane is used for the loading or unloading of whole cargoes, the hire is at the rate of thirty florins the day.

If the crane has to work from noon to one in the afternoon, an additional payment of three florins is made independent of and in addition to the price indicated in the tariff.

An additional payment of three florins with a minimum of six florins is made independent of and in addition to the price indicated in the tariff.

For the use of all the cranes, moveable or fixed, the hire is increased 30 percent on Sundays and holidays.

The use of the coal-tip is rated at 0.10 fl. per 1000 kilogrammes.

The following are included under this tariff: the hauling of the waggon from the special railroad to the apparatus, the placing of it on the platform, the unlocking of the shutter towards the shoot, the tipping and return of the waggon to the rail.

In case the conditions of the shoot are not satisfactory, the Director is authorised to increase the tariff, according to circumstances, to the amount of 50 percent.

The weighing, effected in the waggons on the weighing bridge, is payed at the rate of fl. 0.025 per thousand kilogrammes net, with a minimum charge of fl. 1.50. The net weight is determined by subtracting from the gross weight the tare inscribed on each waggon.

A certificate stating the total weight of the amount loaded or unloaded can be obtained on application.

For night work or on Sundays or holidays the tariff of the coal-tip is increased 30 percent.

The following tables make clear the working results of the plant since the commercial establishments belong to the town.

Steam Cranes.

YEARS.	Working hours.	Working Expenses.	Proceeds from hire of cranes.	Average number of cranes working daily.	Labour expenses per hour.	Consumption of coal per hour in hectolitres. (1 hecto. — 85 kil.)
		Florins.	Florins.		Florins.	
1883	13845	8569 655	17353.53	4.—	0,6190	0,335
1884	14644	8445.105	17524.99	4.—	0.5770	0,363
1885	17115	10298.530	18881.02	5.—	0,6020	0,341
1886	15644	8116.575	16279.20	4.25	0,5188	0.324
1887	20345	13099.915	20947.29	5.50	0,6439	0.328
1888	20886	13496.980	21912.86	5.50	0,6462	0.337
1889	21084	13250.945	22565.87	6.—	0.6285	0.353
1890	26651	18813.745	28022.43	7.—	0.7059	0,344
1891	33065	20485.375	34159.15	8.87	0.6195	0,319
1892	33336	20388.260	34267.46	9.—	0,6116	0.305
1893	34752	22103.300	36845.54	9.36	0.6360	0.335

There were twenty three steam cranes.

Hydraulic plant.

YEARS.	Hours worked by the pump. (Hours by steam).	Days worked by the pump. (Days by steam.)	Average numbre of hours by steam per day.	Working expenses.	Hire of engines.	Average number of engines working per day.	Expenses per engine per day by steam.	Consumption of coal per hour in hectol. (1 hecto. — 85 kilos.)
				Florins.	Florins.		Florins	
1883	1536	166	9.30	3864.260	3865.91	1.50	15.52	1.20
1884	1879	195	9.60	4204.135	4266.07	1.60	13.48	1.11
1885	1809	197	9.20	3863.630	4365.04	1.60	12.26	1.28
1886	1870	195	9.60	4348.190	4655.96	1.80	12.39	1.18
1887	1458	157	9.30	4763.135	3135.86	1.60	19.58	1.32
1888	2389	226	10.60	4964.185	5887.04	1.80	11.94	1.29
1889	2480	235	10.60	5651.515	7304.33	2.40	10 15	1.29
1890	2659	255	10.40	6878.360	9245 68	2.80	9.50	1.32
1891	3165	279	11.30	8410.490	11355.40	2.80	10.61	1.16
1892	4411	320	13.78	11555.560	16583.70	3.12	11.57	1.37
1893	4708	300	15.69	11788.920	17968.83	3.19	12.32	1.32

The labour expenses of the engines and buildings are included in the Working Expenses.

The profits of the steam cranes were 13879 florins in 1892, and 14742 florins in 1893.

Cost of the 22 moveable cranes	fl. 176.000
- - - fixed crane, including its foundations	- 40.000

Returns to the amount of about $6^1/_2$ $^0/_0$ are at present obtained, and this may be considered sufficient for the payment of interest and the sinking of the capital.

The profits of the hydraulic plant were 5028 florins in 1892, and 6180 florins in 1893.

Cost of original plant	fl. 190.000
- - the coal-tip	- 66.000
- - two cranes joined together	- 17.750
Total	fl. 273.750

The working results therefore of this part of the plant are not considerable: only about 2 $^0/_0$ is obtained for the payment of interests and the sinking of the capital of the original plant. These results even would not be obtained without the most active labour on the part of the coal-tip.

Therefore a manner of further developing our port has seriously to be considered.

We can not think of breaking up a capital, which still pays an interest of 2 $^0/_0$, and, besides, the chance of increasing the interest becomes more favorable in proportion as the work is conducted on a larger scale. It has therefore been decided to increase the present hydraulic plant of the Binnenhaven, but to choose an other motive power for the plant to be put up on the Rijnhaven.

The hydraulic plant has two great inconveniences. In the first place the central machine must be placed in sight of the largest number of engines, and nevertheless it only works occasionally and then only at short intervals at full pressure. To be convinced of this one has only to watch how an engine in the central building works. In the second place, each engine always works at full pressure, except when it is a question of obtaining less effective results. A crane made to lift from 750 to 1500 kilogrammes will always use 1500 kilogrammes power, or the same quantity of water, even where it has only to lift 800 kilogrammes.

Ordinary steam cranes give better working results than hydraulic cranes.

Nevertheless, if for the requirements of the railroads along the warehouses on the quays, it is a question of using high horse-cranes instead of Brown's system of crane, which has not much height, steam cranes present inconveniences which have to be contended with. They increase the risk of fire and necessitate the hoisting up of water and coal.

The great impetus given of late by the transmission of motive power to a distance by means of electricity has naturally attracted our attention.

The town, which does its own gas lighting, had decided in addition on the establishment of a central station for electric lighting and the transmission of motive power, for the benefit of public buildings and private individuals.

As an experiment a quay crane moved by electricity was put up in 1892. At the same time two cranes of the same kind were put up at Hamburg by different builders.

The results have been satisfactory to the degree, that it has been determined to set up provisionally six other electric cranes, which will be placed during the present year on the Wilhelminakade.

Messrs. NAGEL & KAEMP, of Hamburg, have undertaken to deliver them upon the following conditions: they will cost 11050 florins each and the makers warrant them to run at 315 watts an hour while engaged on the following work: a load of 1500 kilogrammes, deposited on the quay, will be lifted to the maximum height, lowered fifteen metres and then be replaced upon the quay on the other side of the crane, at a point diametrically opposite to its original position.

On account of the heavy fine they incur, if they fail to fulfill these conditions, Messrs. NAGEL and KAEMP are not willing to warrant a less consumption of electricity, but they are convinced, that if the power, which by the descent of the load is returned to the cable, be subtracted from the effective power required, they will run at 240 watts the hour to perform the work just described. This consumption of electricity is indicated by the experiments made with the crane, that the firm has put up at Hamburg, the construction of which is in the main identical with that of those to be put up at Rotterdam.

The town is building near the gas works a central station, where electricity will be produced under a tension of 700 volts in a continuous current. This electricity will first be directed to two accumulation stations, one on the right the other on the left bank of the Meuse, whence it will be divided upon the system of five conductors. The cranes can work with a tension of 440 volts. The central engines can work continually at full pressure; by day, principally for the service of the cranes; by night principally for lighting purposes.

The energy which is not used at the time of production is stored in accumulators, from which it is taken when required.

The engines are always ready to work and only use electricity at the moment of lifting or turning round. Upon the descent a certain quantity of the electricity is returned to the system, because the motors then revolve in the opposite direction. Under these conditions it is hoped that more remunerative and at the same time safer working results will be arrived, since the most severe frost can not interfere with the working of these engines.

In the warehouses of the Wilhelminakade electricity is already used with success to move various lifting apparatuses. They receive the motive power from a provisional station, but they will later be connected with the town system.

Besides the cranes belonging to the town there are also on the left bank, on the ground of the station of the State railway:

A hand crane of	3000 kilos power.
» » »	4000 » »
Eight moveable steam cranes of	1500 » »
Two » » »	» 3000 » »
A coal-tip for coal waggons, at the service of the inland navigation, able to tip waggons of	15000 kilos.
A steam crane at the ship-building Establishment at Feyenoord of	60000 » power.

Lastly, a private company hires out two machines for masting ships, the one capable of raising 15000 kilos, the other 20000 kilos.

Vessels lying along the quays are free to make use of the plant of the town or that with which they are provided for the loading or unloading of their cargoes. The town also hires out the small plant necessary for this purpose, according to the following tariff per diem:

Six wheeled carts, carts on castors, wheel barrows, each	fl. 0.35
Four wheeled carts	» 0.20
» » » with saddles	» 0.25
Drays	» 0.20
Levers, handspikes, crow-bars, shovels for ballast, grain &c., davits, sugar tasters, clasps	» 0.10
Hand hammers, adzes, forceps, each	» 0.05
Loading bridges	» 0.25
Chains, fluked chains &c., rail crow-bars unloading sheets & nets, rope ends, blocks	» 0.20
Lanterns, large size, filled	» 0.50
» small size	» 0.35
Tables	» 0.25
Grain baskets	» 0.40
Fans	» 0.40
Ladders	» 0.30
Unloading buckets	» 0.40
Jacks	» 0.50
Windlasses	fl. 0.50
Oak troughs	» 0,35
Iron unloading buckets	» 0.35
Iron tipping buckets	» 0,50
Ore troughs, three-cornered	» 1.00
Duckham weighing machines of 30000 kilo power	» 4.00
Ditto of 3000 kilo power	» 2,00
Scales with weights, 3000 kilo	» 3,00
» » » 2000 to 1000 kilo	» 1.50
» » » 1000 kilo or under	» 1,00
Large balance with weigts &c.	» 2.50
» » with awning	» 3,00
Balance with weights &c.	» 1.50
Grain troughs	» 1,00
Grain reservoir	» 1.50
Trestle sets with boards	» 1,00
Scaffolding boards, each	» 0.20
Hand cranes	» 1,50

Fractions of days are counted as whole days.

The use of the weighing bridge for the weighing of waggons, which can carry 20.000 kilos, is charged at the rate of fl. 0.75 per waggon with a minimum charge of fl. 1.50.

All this goes to show that the greatest liberty and facility is offered with respect to the use of the fittings of the port.

DRY DOCKS.

It is indispensable that the organisation of a sea port should comprise all that is necessary for the examination, cleaning & repairs of vessels.

Until 1883, private companies, which exist still, alone provided these. They were:

(1) Messrs. S. TH. VAN LEEUWEN & Co., who worked a wooden floating dock 88 metres long and 16.15 metres wide, inside measurement, for vessels drawing not more than fourty two decimetres of water.

(2) The Société Générale for refitting docks on the Westzeedijk and

(3) The Noordereiland refitting Dock company.

Each of these companies has a dock for vessels of 1200 tons.

Rotterdam and its environs also possess a certain number of establishments for the building and repairing of sailing or steam river craft.

However, the Lloyd of Rotterdam and the Netherland-American steam Navigation Company introduced into our shipping vessels of a size too great to enter the then existing dry docks. The need has been felt from that time of a dock of dimensions corresponding to those of the largest vessels that can come up to Rotterdam.

It was not however possible to form a company, which would run the risks attached to such an undertaking. A very large sum of money was required, and on the other hand, the results of the improvement of the navigable route from Rotterdam to the sea were not yet assured.

The town therefore decided in 1880 itself to do what was necessary. The establishment of fixed docks in masonry in our country presents the greatest difficulties, on account of the instability of our soil, and these difficulties could only be overcome at the expense of very considerable capital. Preference was therefore given to the system of floating docks of iron.

The latter have moreover this considerable advantage in working over excavated docks, viz. that the ships, once out of the water, dry more quickly by reason of the wind, which plays more freely on both sides of them.

Instead of one large dock, two were made; one of ninety, the other forty eight, metres in lengt with an equal width for both of 27.40 metres over-all measurement and capable of raising, besides their own weight, 44000 kilos per metre in length.

The dock of ninety metres was able to receive vessels one hundred and ten metres long, the largest which at that time frequented our port. The smaller dock could take in vessels up to seventy metres in length. Lastly, by coupling the two docks lengthwise, an apparatus was created capable of receiving a vessel a hundred and fifty metres long, with a maximum weight of six million kilogrammes. It has been necessary in fact several times to employ this method of coupling.

On the left bank of the Meuse, the special basin named Dokhaven has been excavated, where vessels can make fast in perfect safety sheltered from the current, which makes it a perfectly easy matter to haul them into the dock. The opening of the town's floating docks took place in October 1883, at the placing in dock of the steamer „Gelderland" belonging to Lloyd of Rotterdam.

With the increase in shipping at Rotterdam the use of the docks increased in like manuer, till the necessity of building a third became evident. The town decided to do so in 1890.

The third dock was opened in February 1893. The length of it is a hundred and ten metres, with a power of raising 55000 kilogrammes per metre in length, or a total of six million kilogrammes. Vessels of a hundred and thirty to a hundred and forty metres and drawing seven metres can enter it. A site has been assigned to this dock, near the other two, due consideration being given to the enlargement of the basin which contains them.

The cost of this structure was as follows:

Construction of the basin with its ware-houses and other buildings . . .	fl. 250.000
Docks I and II	- 830.000
Enlargement of the basin	- 40.000
Dock III	- 740.000
Total . . .	fl. 1.860.000

The use of the floating docks is subject to a special charge called „*dokgeld*", of which the following in the tariff:

Gross tonnage of vessels in cubic metres.	Cost of entering & leaving the dock.	Hire of the dock per day.
	Per cub. m.	
Vessels of 250 cub. m. or less to 400 cub. m. . .	Florin 0.09	For the first 5 days 3 cents per cub. m. per day. For subsequent days 2 cents per cub. m. per day.
Nom 401 to 450. . . .	„ 0.085	
„ 451 „ 500. . . .	„ 0.08	
„ 501 „ 750. . . .	„ 0.075	
„ 751 „ 1000. . . .	„ 0.07	
„ 1001 „ 2000. . . .	„ 0.065	
„ 2001 „ 3000. . . .	„ 0.06	
„ 3001 „ 4000. . . .	„ 0.055	
„ 4001 and over . . .	„ 0,05	

With regard to the entering and leaving the dock, it is understood that this tariff is never to be interpreted so that a vessel of large tonnage is subject to smaller charges than a smaller vessel.

With respect to the manoeuvres of entering and leaving the dock, as well as the hire ot it, the above tariff is increased 25 °/₀ for vessels which make use of the two docks of 48 & 90 metres coupled together, and 50 °/₀ for those of particularly heavy construction, such as armoured vessels.

By gross tonnage is meant that indicated by the tonnage certificate issued by the State.

In default of this certificate or some other document showing the tonnage sufficiently nearly, or upon the refusal to produce the documents desired, the vessel is rated according to established rules, or rules to be established by the state, and this operation is performed by an expert provided by the corporation.

When, upon its entrance into the dock, the vessel is partially loaded, the duty is charged not only on its gross capacity, but also upon the amount of the cargo valued at the rate of 2 cub. m. 83 centimetres per thousand kilogrammes in weight, the tonnage of the vessel and amount of cargo being added together.

The length of the vessels may without inconvenience be 18 metres greater than the docks used.

Steam boats, pumps, capstans, windlasses, electric light and other accessories can be put at the disposal of those who require them at a fixed tariff.

The following table shows the working results.

YEARS.	VESSELS EMPLOYING DOCKS.								TOTAL.		Working expenses.	Charges made.	Net profit.
	N°. I. length 48 metres.		N°. II. length 90 metres.		N^os^. I & II. coupled.		N°. III. length 110 metres.						
	Number of vessels.	Number of days.	Number of vessels.	Number of days.	Number of vessels.	Number of days.	Number of vessels.	Number of days.	Number of vessels.	Number of days.			
											Florins.	Florins.	Florins.
1884	18	92	43	196$^9/_{10}$	1	3½	—	—	62	292$^2/_5$	14049	50146	36097
1885	14	42	44	166	—	—	—	—	58	208	14174	41734	27560
1886	6	73	51	164	—	—	—	—	57	237	15107	43253	28146
1887	10	57	48	160	—	—	—	—	58	217	14678	45978	31300
1888	19	62	62	198½	2	5	—	—	83	265½	18368	60508	42140
1889	28	111	72	237	3	6	—	—	103	354	24499	73776	49277
1890	30	103	57	209	8	48	—	—	95	360	18190	85329	66419
1891	36	173	75	194	10	29	—	—	121	396	25091	84487	59396
1892	36	125	65	215½	7	27	1	2½	109	370	15310	85083	69773
1893	34	132½	52	191¼	1	3	41	140½	128	464½	29372	107692	78320

The labour expenses of the docks themselves and the basins containing them are included in the Working Expenses.

One of the most important factors in the evolution of a sea-port is a good connection with the railway systems. The more the number of railways increases, spreading out in every direction throughout the country behind this port, the greater is the chance opened for an increased traffic on these lines — a circumstance which contributes singularly to the prosperity of the country. The contact of the port and the railroad should however be immediate; between the one and the other there should be no considerable distance, for fear the expenses of intermediate communication reach too high a figure.

Railway traffic is classed under two principal categories, that affecting local interests and that of transport.

The traffic affecting local interests comprises either food stuffs, which accumulate in considerable quantity in the warehouses to be dispatched once more to different parts by land or water, or goods to be taken by merchants of various classes, who sell them over again retail.

For the profitable working of ware-houses it is important, that they should be in connection with railroads on the quays and thus reduce the local expenses to a minimum. What I have said with regard to the ware-housing of goods has reference to this.

With respect to the category affecting various merchants and private persons, it is important, that the goods station shall not be at too great a distance, because otherwise in a large town the cost of carting might reach a figure quite out of proportion to the value of the commodities. The number of local goods stations therefore should be regulated bij the importance of the town.

In my opinion, a town such as Rotterdam ought to have at least four. We have at present three, one in the north end of the town (the Gate of Delft Station), one in the east end (the Meuse Station), and one in the south (the Feyenoord Station).

On account of the development of the west end of the town and the harbour works, which are already projected there, it will become necessary to have a fourth station for local traffic. People sending or receiving goods will then be able to choose whichever of the four stations it will be most to their pecuniary interest to use. But for this purpose it will be necessary for the stations to be connected with one another. The Gate of Delft Station and the Feyenoord are already in communication and the junction of the former with the Meuse Station is in course of execution by means of a circular railroad in the north of the town.

With regard to transport, a distinction must be made between goods *en masse* and packages. For example, ores, coal, timber, grain, which land in whole cargoes to be transported further by boat or rail, belong to the first category. If it is by rail, spacious quays without sheds and many lines are an absolute necessity.

A vessel which brings 3000 tons of ore, and that is not a large vessel, requires 300 waggons for the transport of her cargo. If therefore several vessels should be near each other along-side the quay, a large number of rails and points will be required in order that they be unloaded promptly and without mutual inconvenience. These operations therefore are commonly carried out at the stations on the docks, the Feyenoord and Meuse stations.

Only when there is not sufficient room, and that sometimes occurs, the east quay of the Binnenhaven is also used for this purpose.

This quay is also devoted to the trans-shipment of German export coal and coke, which arrives in numerous waggons which require to be rapidly unloaded. This naturally necessitates a spacious site and the large number of rails met with at this point. The unloading of sailing vessels is also generally, done on the west side of the Binnenhaven, but it occasions less inconvenience, because generally speaking it does not take place at the same rate.

Goods in packages are especially brought or taken by ships of mixed cargo, which are served by fixed lines and have their positions reserved along the quays. It is therefore of the highest importance, to reduce the local expenses to a minimum, that the waggons shall be able to come and take or deliver their loads in the immediate neighbourhood of the ships.

The shipping lines, which have fixed positions on the right bank, do not yet enjoy this advantage· Until the last few years the need has not made itself much felt, because the cargoes can evidently bear greater expenses and because a service of lighters established between the railroad and the vessels and vice versa supplied this need in a certain measure.

However, the competition of neighbouring ports, every day more active, has already obliged certain lines to move their positions to the left bank of the Meuse, and most certainly when the works for the development of the arrangements on the right bank shall be complete other steamers will have the benefit of the positions, which will be in connection with the railway lines. When the project of establishing works was promulgated by the Commercial Association of Rotterdam, the idea was to connect the quays with the railroads. A branch line, passing over the bridge which spans the southern mouth of the Spoorweghaven, connects the Feyenoord goods station with the quays of the Binnenhaven and with those on the east side of the Spoorweghaven. All along the warehouses on the latter there is but one rail at the water's edge for the removal of goods, because the second has to remain at the service of the cranes. This is certainly a mistake, for the direct communication by rail with the vessels lying

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north of the Spoorweghaven, is much impeded. The consequence of this is that with the exception of the arrivals of coal for the bunkers and certain goods of great weight, hardly anything passes or can pass over this line.

It has been necessary to lay down three others, behind the ware-houses, so that goods in packages to be despatched by rail cannot reach the lines without passing through the sheds. For certain goods, subject to customs formalities, this does not present any great inconvenience; but for others the case is not the same. Therefore along the new quays of the Rijnhaven two lines of rails have been laid down near the water. The use of horse-cranes nevertheless has allowed of no greater distance being left than between the shed and the water's edge on the Spoorweghaven. At this point the two systems of open and covered quays have been connected. In the middle of the quay an open space has been reserved for ships that do not require sheds, and this arrangement greatly facilitates the traffic passing over the railway and the quay. Turning platforms and transverse rails are always in the way, especially for the use of carts, so that almost all apparatus of this nature, put down in 1873, at the commencement of operations, has been removed.

The town of Rotterdam has by purchase become owner of this land outside the dam on the left bank of the Meuse. This acquisition presents a development in length of more than nine kilometres and about 365 hectares in area.

On this space the harbour works now existing have been put up and others will be erected in proportion to requirements according to plans already complete. The construction of the new manufacturing quarter of Rotterdam has also been planned, to the east of the railway embankment, and is to day sufficiently advanced for part of the quarter already to be at work.

The greatest care has been given, it will be readily conceived, to the connection with the railroad, so that every part of the docks, as well as every factory in the quarter, may be accessible by means of rails. That however is not enough; it is necessary that the working of such secondary branch lines may not only be certain, but also as cheap as possible. When as is here the case, the management of the railway and of the port is not in the same hands, there ought to be an agreement for a sufficiently long time.

Railways need ports to keep them going. On the other hand it is impossible to imagine a port properly worked without the help of railways.

There is therefore mutual interest which should serve as the basis of the contract; the two parties should have in view the extension of the movement as a source of immediate profit.

In 1889 a convention for the laying down and use of railroads on the land on the right bank of the Meuse, which belongs or will belong, either by possession or favour, to Rotterdam, was concluded between the town and the Company for the working of State railroads. The following are the principal clauses of the agreement.

(1) The Company obliges itself:

A. To describe in all its tariffs for the transport of goods as a special station at the same rates as the Feyenoordstation the land between the shipyard of Feyenoord and the western boundary of the site let to the American Petroleum Company.

B. If the rails should be carried further west than the above boundary, as has already been done to connect the petroleum yard of Messrs. RIETH & Co., not to apply a higher tariff than that indicated under A, at an increase only of fifteen cents per ton.

(2). All working expenses, all charges, all responsibility incurred by the use of the railway are borne exclusively by the Company.

(3) The town builds the road and keeps it in order, i. e. the embankments and bridges; viaducts and other works necessary, and the company builds and keeps in order the superstructure, i. e. the rails, sleepers, points and turning platforms.

(4) Out of the profits acquired by the Company from the transport to or from the merchant sites the Company puts by annually a certain sum, from which, in addition to other small dues, the town is payed fifteen cents per metre in length for the proper maintenance of the road and 0.025 of a florin per thousand kilogrammes of goods brought to the merchant sites or entrances of the said sites.

(5) The company obliges itself to admit on the merchant sites trains of other railway companies and to concede to them the use of the rails and points, upon the same conditions, upon which according to the law it would in similar circumstances be obligatory for this use to be conceded on any railroad in the Netherlands. The discount of receipts obtained under this head will be effected as explained under (4).

(6) The agreement is made for a period of twenty five years, with the necessary stipulations in case of the lengtening of the contract, the purchase of the lines by the State &c.

This arrangement has insured the proper working by means of railroads of the docks and land devoted to trade uses. Neither the consignees of goods brought by sea, nor those who arrange for their transshipment, have anything to pay in addition to the ordinary tariffs for transport one way or the other, any more than the owners of factories on land belonging to the town. On the other hand by the dues which it is sure of on account of the length of the lines of the system and the importance of the shipping movement, it is to the interest of the latter to do all in its power to benefit this movement.

If the projected works on the right bank of the Meuse, in the western part of the town are ever carried out, there will be a new station there for shipping and trade purposes which will naturally be connected with the other stations. It will then be necessary to build on the circular railroad a large sorting station, to which the goods trains will be sent unsorted, in order that the classifying of the waggons intended for each of the other stations may here be carried out. In every station for shipping purposes there ought also to be sidings on which the sorting of waggons intended for various quays and factories may be performed.

By this means alone even in case of the blocking or obstruction of the port by ice, the railway companies will be able to derive all the profit possible from the plant at their disposal.

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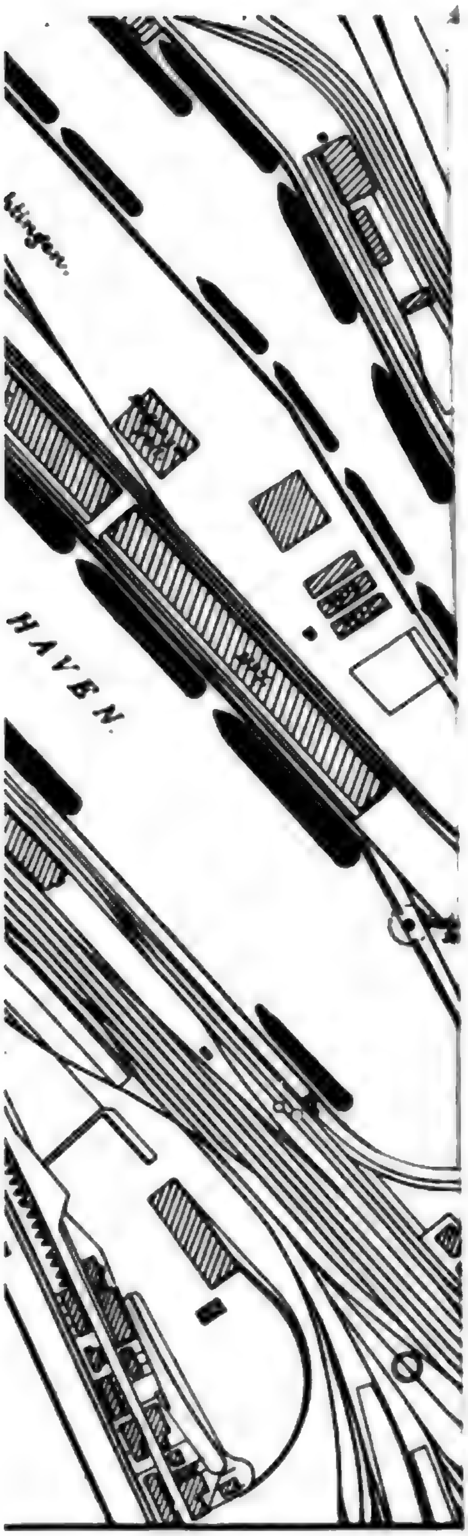

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VI$^{\text{th}}$ INTERNATIONAL INLAND NAVIGATION CONGRESS
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THE PORT OF AMSTERDAM

BY

J. A. SCHUURMAN,
Chief Engineer & Director of Public Works.

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The value of a seaport depends upon its accessability from the sea at all times, its depth of water, safety, freedom from tolls and dues and its facilities for rapid time-saving work; also upon its numerous and direct land and water connections inland allowing of a speedy and economical transit of merchandise in all directions.

A port which by its position possesses these essential advantages fulfils the conditions which ought to assure its progress and prosperity in the commercial world. The construction of docks, quays, wharfs, sheds, warehouses, bonded warehouses and depots, and the laying and organising of railway connections will be carried out as the need for them becomes felt.

Certain European ports are so well placed geographically and so well fulfill the above requirements that not only do they attract ships of regular lines of sailing but they seem also to be the natural door for a wide stretching continental transit trade. This again reacts favourably upon their export trade and thus in these favoured ports imports and exports grow together, for it is certain that ships are sent preferably where a return cargo is most likely to be had.

Favoured by the completion of the North Sea Canal and of the avant-port of Ymuiden in 1876, and by shortened and improved railway connections with Germany, and still further benefited by the opening of the Rhine Canal in 1892, Amsterdam has again had the road laid open to her for the revindication of her right to the title of a commercial city, entrepot and port of transit.

The extension of her relation with the East- and West Indies is shown by the ever increasing prosperity of her regular lines of steamers e.q. the „Nederland", „Océaan", and the „Koninklijk West Indischen Maildienst".

The continental (European) trade of Amsterdam is not less important. Several independant and private lines of steamships, as well as the important and flourishing „Koninklijke Nederlandsche Stoomboot Maatschappij" cultivate this trade assiduously and sail regularly to the Mediterranean, Baltic and North Sea ports, as well as to those on the coasts of France and Portugal.

As an entrepot and transit port too Amsterdam disposes of docks and quays of more than considerable extent and constructed since 1875. With her uniform and almost invariable depth of protected water, at all times calm exists in her basins.

That the expeditious loading and unloading of cargoes in her port is appreciated, is shewn by the following table from which the yearly increase of tonnage may be gathered:

Tonnage.	cub. metres.	Tonnage.	cub. metres.
In 1876		In 1885	2399
„ 1877	1579	„ 1886	2349
„ 1878	1603	„ 1887	2309
„ 1879	1766	„ 1888	2427
„ 1880	1826	„ 1889	2454
„ 1881	1841	„ 1890	2508
„ 1882	2069	„ 1891	2656
„ 1883	2255	„ 1892	2790
„ 1884	2291	„ 1893	2890

Once through the locks at Ymuiden the vessel approaches a port which for accessibility, wharfage and equipment amply fulfils the conditions above mentioned.

From the sea the port of Amsterdam is reached by the port of Ymuiden and the North Sea Canal.

Formerly it is true the North Holland Canal and the Zuiderzee by the Orange locks afforded access from the sea but by seagoing vessels of any size this approach is no longer used, though it still serves for smaller inland river craft.

The North Sea Canal, toll-free since 1890, can accommodate ships 135 metres (about 443 ft.) long, by 16 m. (52 ft.) beam, and drawing 7.20 m. (23 ft. 6 in) of water. There is being constructed at Ymuiden another lock 225 metres (731 ft.) long, 25 m. (82 ft.) wide, and 10 m. (33 ft.) deep. When this is finished ships with a draft of 9 m. (29 ft. 6 in) will be able to proceed up the North Sea Canal to the port of Amsterdam.

Besides the Ymuiden locks, vessels for Amsterdam pass through an ordinary road-bridge at Velzen and through two railway bridges; one at Velzen on the Haarlem—Alkmaar railway, and the other on the North-Holland Amsterdam—Zaandam line. A little time is thus lost, but still from the sea to Amsterdam vice versa 3 hours suffice.

The following table will show the growth of traffic on the North Sea Canal:

TOTAL TONNAGE PASSING THROUGH THE NORTH SEA CANAL.

Year.	OUTWARD BOUND:		INWARD BOUND:		TOTAL:	
	Number.	Tonnage cub. M.	Number.	Tonnage cub. M.	Number.	Tonnage cub. M.*)
1877	1706	1.462.178 net.	1607	1.421.598 net	3376	3.965.192 gross
1878	1655	1.581.504 „	1587	1.601.369 „	3242	4.376.350 „
1879	1919	1.857.833 „	2094	1.953.980 „	4013	5.241.242 „
1880	2214	2.107.188 „	2281	2.157.774 „	4495	5.864.322 „
1881	2266	2.320.927 „	2337	2.269.397 „	4603	6.311.695 „
1882	2321	2.580.370 „	2353	2.595.325 „	4674	7.116.580 „
1883	2773	2.742.049 „	2821	2.695.242 „	5594	7.476.275 „
1884	2776	2.979.764 „	2660	2.952.598 „	5436	8.156.947 „
1885	2744	3.022.977 „	3067	3.031.295 „	5811	8.324.624 „
1886	2852	3.119.774 „	3090	3.133.351 „	5942	8.064.365 „
1887	3019	4.077.128 gross	3237	4.137.604 gross	6256	8.214.732 „
1888	3277	4.224.520 „	3582	4.339.001 „	6859	8.653.521 „
1889	3231	4.434.242 „	3560	4.456.769 „	6791	8.891.011 „
1890	3514	4.705.791 „	4238	4.722.321 „	7752	9.428.112 „
1891	3863	5.095.539 „	4286	5.131.965 „	8149	10.227.505 „
1892	3536	5.253.412 „	4507	5.231.726 „	8043	10.485.138 „
1893						

Comparing the tonnage of 1877 when the North Sea Canal was first opened with that of 1893 it is seen that the number of vessels passing through it has increased 130 % and the tonnage 170 %.

The number of ships which entered the port of Amsterdam figures thus:

In 1877	1540 withh a gross tonnage of	2.431.715 cub. m.
„ 1878	1472 „ „ „ „	„ 2.360.287 „ „
„ 1879	1526 „ „ „ „	„ 2.694.289 „ „
„ 1880	1614 „ „ „ „	„ 2.947.164 „ „
„ 1881	1658 „ „ „ „	„ 3.052.218 „ „
„ 1882	1702 „ „ „ „	„ 3.504.942 „ „
„ 1883	1607 „ „ „ „	„ 3.624.283 „ „
„ 1884	1698 „ „ „ „	„ 3.889.061 „ „
„ 1885	1635 „ „ „ „	„ 3.922.974 „ „
„ 1886	1576 „ „ „ „	„ 3.701.722 „ „
„ 1887	1600 „ „ „ „	„ 3.693.747 „ „
„ 1888	1576 „ „ „ „	„ 3.824.390 „ „
„ 1889	1642 „ „ „ „	„ 3.964.112 „ „
„ 1890	1675 „ „ „ „	„ 4.200.409 „ „
„ 1891	1723 „ „ „ „	„ 4.575.942 „ „
„ 1892	1632 „ „ „ „	„ 4.533.662 „ „
„ 1893	1558 „ „ „ „	„ 4.512.347 „ „

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*) From 1877 to 1887 the totals are approximate.

It will be seen that whilst the number of vessels entering the port of Amsterdam since 1877 has varied little, the tonnage has increased 86 %.

The access from the Zuiderzee by way of the Orangelocks at Schellingwoude is destined for the use of craft visiting the north eastern ports of Holland, and is therefore mainly given up to the Zuiderzee coasting trade.

The sill of the Orange-locks is at a depth of 4.50 m. ÷ AP. so that with a level of 0.50 m. ÷ AP. vessels may draw 4 metres (13 ft.) of water. A very large total tonnage passes through these locks: Thus in 1892: 25 seagoing vessels (barques, brigs and schooners); 12157 steamers, 28729 inland sailing craft, and 53141 sloops and fishing boats, making a total of 94052 craft of various build.

By the North-Holland Canal, now used mainly for inland traffic, the Rhine Canal, the Amstel, and various other canals and waterways, Amsterdam now possesses abundant and excellent means of communication with the Rhine and inland provinces. In 1892 there arrived in the port of Amsterdam 88.783 inland, river and canal craft, with a total tonnage of 2.777.618 cubic metres.

By the declarations made at Lobith of arrivals from and departures for Amsterdam we can see the augmentation of traffic with the Rhine district. The figures are for the year 1883 a total tonnage of 149.000 cub. metres and for 1893 — 197.000 cub. metres giving an increase of 24 %.

The port of Amsterdam is also advantageously connected with the European railway systems. It is connected to *Essen* by way of Hilversum, Zutphen and Winterswijk; with a branch from Zutphen by Hengelo to Salzbergen and another branch from Hengelo through Enschedé to Gronau. Cologne is reached through Utrecht, Arnheim and Emmerick and also by way of Utrecht, Boxtel, Venloo, Wesel and Gladbach; Cleve through Amersfoort, Kesteren and Nimégue. There is a line running through Haarlem, Rotterdam, and Roosendaal to Antwerp. By Utrecht, Bois-le-Duc and Tilbourg to Turnhout; also by Utrecht, Bois-le-Duc, Eindhoven to Liege; and through Zaandam, Enkhuisen, Stavoren, Leeuwarden and Groningen to North Germany. North Germany is also reached by Amersfoort, Zwolle and Groningen.

After this general view of the numerous channels of communication which unite Amsterdam with the continent generally, we will review the work and organisation of the port Amsterdam itself, and later the commercial resources and the advantages it offers.

A. Docks.

The port possesses docks where merchant-ships and trading vessels, moored to bollards and buoys can tranship their cargoes into inland canal and river craft.

(*a*) The *Diked-in-Y* (*Banked-off Dock*): The best berthing and discharging part of this dock lies between the Handelskade (commercial quay) and the embankment running parallel to it at a distance of 230 metres. This quay is in direct communication with the North sea canal, whilst craft from the Rhineprovinces can reach it by the Rhine-canal and other river boats from and by the numerous other canals and waterways which open into this dock. The dock has a superficial area of about 13 hectares (32 acres), and a depth of 8.20 m. ÷ AP. (26 ft.), so that at a level of 0.50 m. ÷ AP., vessels drawing 7.50 m. ($22^1/_2$ ft.) may still enter and berth in it.

The embankment above referred to was constructed in 1890, and with the mooring buoys cost 480000 florins Its object was to prevent the forming of waves during violent north winds, and to secure permanently smooth water in the basin. It forms the first portion of a new Commercial Quay as indicated by the dotted lines on the plan, and will be completed when required by increased needs of accomodation for merchant ships.

Ships are moored to bollards fixed in the embankments and to floating buoys anchored to screw-moorings. In this basin 24 sea going ships can be moored. A buoy with chain and screw-mooring costs 1400 florins. In deep water or bad bottoms as here, bollards (or piles), wich cost 1500 florins are not to be recommended.

(*b*) *The East Dock:* This dock has an area of 15 hectares (36 acres), a depth of 6.50 m. (about 21 ft.). It communicates with the Diked-in-Y by two locks 15.4 metres and 9 metres wide with the sills at 6.25 metres and 5 metres ÷ AP. respectively. Above these locks which are generally left open, there are two swing bridges, one for the road and the other for the railway. This latter is generally required to be kept closed for railway traffic and this often stops ships and loses time for such as stil favour this old dock. Plans are in preparation for a deviation of the line of railway for the purpose of correcting this.

In this dock 31 vessels can be accomodated. It is mainly used by sea going vessels whose cargoes are to be warehoused in the east end of the town, and by those transhipping merchandise on to the Rhine boats. The dock communicates with the government Marine Dock, with the new canal (and through this with the Rhine canal) with the building yards and factories along the Kattenberg and Wittenberg cuts, and by the Oude Schans and the Heerengracht with the central part of the town.

On the north side there is a 40 ton masting shear.

(*c.*) *The West Dock.* — This basin, also old, has on its west side building yards, work shops and warehouses. Its area is about 12 hectares (30 acres) and its depth 5.50 m. (17$^1/_2$ ft.). By the Westdock-locks, 13.84 and 7.85 metres wide and 5.90 and 3.82 m. deep respectively, it communicates with the „Diked-in-Y'', whilst by the Princes Canal, the Zoutkeetsgracht and the West Canal, the numerous warehouses in that neighbourhood are to be reached and also the inland waterways.

Above these locks usually open are two swing-bridges for the cart traffic and the railway respectively. This latter railway serves exclusively for goodstraffic to and from the West dock and wharfs. It offers consequenty less obstacle to shipping than does the railwaybridge over the East dock locks. The navigation of the present day however demands docks accessible at any time.

For this reason the construction of the open basins *a* and *d* whose area exceeds that of the East and West docks was insisted upon.

The West dock offers space for 15 merchant ships, and is mainly used for embarcations loading or discharging for the depots and warehouses in the West part of the city

(*d.*) *Outer port of the Timber Dock.* — Constructed at the same time as the Timber dock 1876—'83, it measures 15$^1/_2$ hectares (37 acres) and has 7.50 metres and partly 8.20 m. (26$^1/_2$ feet) depth of water. It is separated from the „Diked-in-Y" by an earthen embankment and from the timber basin proper by a wooden pier or paling. A 30 metre opening in the earthen embankment gives access to the „Diked-in-Y", whilst the inland canal and river system is accessible through the West Canal which is 3 metres (10 ft.) deep.

Sixteen sea-going vessels of largest size can here moor to the bollards to tranship cargo into the smaller river craft.

Before concluding this part of my report, I would express my opinion that, in projecting a basin for sea-going vessels the following conditions should as far as possible be fulfilled:

> *The entrance to any basin or dock intended for sea going ships should coincide with the direction of the channel of approach, and be unobstructed by locks or bridges.*
>
> *River craft must be able to come alongside the larger sea craft. There must therefore be a good clear channel of approach for the former, of a minimum depth of 3 metres (9$^3/_4$ ft.).*
>
> *There must be smooth water in the channel and basin at all times so that even in windy weather loading and unloading may stil go on uninterruptedly.*

B. Quais.

(*a.*) *Oostelijke Handelskade* (East Commercial Quay). — Amongst the quays for loading and unloading cargo the East quay must be put first and foremost. Constructed by the town at a cost of more than 3.375.000 fl. (£ 281.250), its length is about 2000 m. (2187 yards) and width 59 metres (64 yards) except at the west end, where for a length of 85 metres it has a width of 110 metres (nearly 120 yards).

For sea going ships the mooring is to the north of it where the „Diked-in-Y" has a depth of 8.20 m. (26 ft.) ÷ AP., so that at a level of 0.50 m. ÷ AP. there is a depth of water of 7.70 m. (25 ft. nearly). For 1200 metres on the south side the quay is bordered by an inner or inland port or basin, for inland craft as implied by the name. This port has an average width of 52 metres (56 yards), and a depth of 3 metres (ft. 9.9 in). As well on the north as on the south side quay walls have been build. The top level of the quay walls and embankments is of 1.50 metres + AP. or of 2 metres (6 ft. 6) above ordinary water level a height which was judged convenient for both sea and inland craft.

On the quay there are laid five, and for a distance six pairs of rails with connecting points and turn tables. These branch lines are connected with the adjoining railway goods-station.

The quay space is suitably apportioned as follows:

On the Nord side on a band or width of 6 metres are laid one line of rails with overhead travelling cranes. Next a 25 metres are occupied by warehouses and sheds. The remaining 28 metres of width is taken up by a siding along the South side of the sheds and warehouses, by a road for ordinary traffic, three lines of shunting rails and a pair of rails carrying the pedestal cranes along the inland port.

Experience has demonstrated the need for two lines of rail along the north front side of the quay for the use of the transit trade. This was foreseen when constructing the three sheds on the east side of the quay in 1891 at public cost. It is true that the distance from shipshold to warehouse and shed is thereby increased but to compensate for this, greater reach was given to the cranes.

On the west side of the quay, at a cost of 235,000 florins, the town has build a general public structure in which are located: the pilot office, telegraph and post offices, a branch of the Royal Netherland Meteorological Society, the custom house offices, and a police station. Thus are brought together the various necessary administrative offices.

The quay is excellently provided with machines and appliances, moved by hydraulic power at 50 atmospheres. On the west side of the quay there are one 30 ton crane, along the north quaywall 23 overhead travelling cranes, each lifting 30 cwt.; one crane with a lifting power of 3 and another of 6 tons.

Along the south quaywall there are 2 movable pedestal cranes to lift 30 cwt; six capstans of 20 cwtpower and 8 movable jigger hoists also lifting a ton each. These travelling jiggers may be used inside or outside the warehouses.

The engine houses are at the eastend of the innerport, and contain two compound horizontal engines each of 90 effective horse power, and there is further space for two more similar engines.

The steam is supplied by six generators whilst three accumulators keep the water at a 50 atmosphere pressure. The water which is forced into the system of tubes returns to the boilerhouse; hence even during the excessively severe frosts of the winter of 1891 work proceeded as usual and without interruption. The cost of this plant amounted to about 570.000 fl. (£ 47,500).

Its working results are figured as follows:

YEAR.	No. of hours (steam) worked by Hydr. Pumps.	No. of days (steam) worked by Pumps.	Average no. of hours (steam) worked per day.	Cost in guilders.	Receipts for use of Hoist-appliances.	Average number of hydr. scrams used p. day	Cost per Hoist per day (steam).	Coal consumption p. hour (steam) in Hectolitres of 85 Kg.	Consumption do per day (steam) in Hectolitres.	Coal consumption per hoist per day (steam).	Receipt per Hoist per day (steam).
1891	4712,5	317	14,86	18813,89	15436,37^5	6,25	9,49^5	1,99	17,82^5	2,852	7,79
1892	5128,5	320	16.026	25885,31	25226,73^5	7,83	10,26^5	1,017	16,3	2,068	10,00
1893	5543,5	326	16,7	26854,98	25388,57	10,006	8,23	1,5	25,04	2,502	7,78

The earnings of the hydraulic plant increase yearly thus:

In 1886 the receipts were 5296 guilders.
" 1887 " " " 10328 "
" 1888 " " " 8190 "
" 1889 " " " 12685 "
" 1890 " " " 10973 "
" 1891 " " " 15436 "
" 1892 " " " 25226 "
" 1893 " " " 25388 "

The tariff for the use of the hydraulic machines is fixed as followr:

A. For the 30 ton shear.

1^0. For shipping or unshipping masts:

(*a*) with a circumference up to 15 decimetres (58 in), at the rate of fl 0.40 per decimetre;

(*b*) For those of larger circumference. an additional 0.05 fl. per decimetre;

(*c*) with yards and shrouds $^5/_4$ of the above charges.

2⁰. For the manipulation of objects other than those above mentioned under no. 1⁰. as follows:

For Objects weighing,	**Loading or unloading.**	**Transhipping.**
From 1501 to 5000 Kg., per 1000 Kg.	Fl. 0.75	Fl. 1.15
„ 5001 „ 10000 „ „ „ „	„ 1.15	„ 1.75
„ 10001 „ 15000 „ „ „ „	„ 1.50	„ 2.25
„ 15001 „ 20000 „ „ „ „	„ 2.05	„ 3.00
„ 20001 „ 25000 „ „ „ „	„ 3.00	„ 3.75
„ 25001 „ 30000 „ „ „ „	„ 4.00	„ 5.00

3⁰. Per day the charge is 30 guilders.

When a piece lifted is required to remain suspended in the air for a time, in addition to the charges under 1⁰. and 2⁰. there is made an additional charge, thus:

Up to 5000 Kilos	5 guilders.
From 5001 „ to 10000 Kg.	8 „
„ 10001 „ „ 15000 „	13 „
„ 15001 „ „ 20000 „	20 „
„ 20001 „ „ 25000 „	30 „
„ 25001 „ „ 30000 „	40 „

The minimum charge made for use of the shear is 5 guilders.

B. For the travelling cranes and the jiggerhoists the charges are:

For use of a travelling crane	1.00 fl. per hour.
„ „ „ „ „ „	5.00 „ „ half day.
„ „ „ a jigger hoist „	0.70 „ „ hour.
„ „ „ „ „ „	4.00 „ „ half day.

The maximum charges for the whole or part of a day are:

For a travelling crane	24 guilders.
„ „ jigger hoist	18 „

For the use of machines on Sundays, or out of ordinary working hours (except from 12 to 1 'oc.), the charges are fixed as follows:

For the use of the 30 ton shear in addition to the sum named ander A	5.00 guilders per hour
For a travelling crane, in addition to the charges namend under B	1.50 „ „ „
„ „ jigger hoist	1.00 „ „ „

At the westend of the Commercial Quay (Handelskade) the town has placed an 80 ton steam crane with a reach of 10.50 m. The crane is close to the railway so that trucks can be brought within its reach. The tarif for the use of this crane and of the one in the Eastdock already referred to under *b*, *A*, is fixed as follows:

1⁰. For shipping or unshipping masts the same charge is made as for the 30 ton hydr. crane.

2⁰. For the manipulation of pieces other than those mentioned under 1⁰., during not more than 24 consecutive hours

Up to 10.000 Kg. per 1000 Kg.	100	cents.
From 10000 to 20000 „ „ „	95	„
„ 20000 „ 30000 „ „ „ „	90	„
„ 30000 „ 40000 „ „ „ „	85	„
„ 40000 „ 50000 „ „ „ „	80	„
Beyond 50000 „ „ „ „	75	„

For pieces weighing from 10000 Kg. upwards, also:

From 10000 to 15000 Kg. per 1000 Kg.	1.25	guilders
„ 15000 „ 20000 „ „ „ „	1.55	„
„ 20000 „ 25000 „ „ „ „	1.85	„
„ 25000 „ 30000 „ „ „ „	2.10	„
„ 30000 „ 40000 „ „ „ „	2.65	„
„ 40000 „ 50000 „ „ „ „	3.20	„
„ 50000 „ 60000 „ „ „ „	3.75	„
„ 60000 „ 80000 „ „ „ „	4.25	„

For use of the 80 ton crane, in addition to the above rates, 5 florins for the first hour and 2 fl. for each following hour is charged.

The Holland Railway Company (who rent for 1400 fl. and work, the railway on the Handelskade) have fixed at the east end of the quai a coal tip and shoot for loading coal into sea going vessels. Its lifting power of 20000 kilo (20 tons) is supplied by the townowned hydraulic machinery at a charge to the company of 0.50 fl. per cub. metre. During 1892, 2359 waggons of coal and coke were dealt with. Table and truck are both lifted together.

Beginning from the west end, on the quay are the following trade properties:

1⁰. A space of ground belonging to the Netherland Steamship company, measuring 10425 sq. m. and used by the company for the necessities of their fortnightly service of mail boats between Holland and the Dutch East Indian Colonies. A stone built storied shed of 1500 sq. m. used by ships receiving cargo; a building used as offices; and a stone built shed put up by the town for incoming cargo; this shed cost 100,000 fl. and measures 2800 sq. metre. It is let to the company for 30 years at 5783 fl. per year. At the expiration of this leave it becomes the company's property. As a rent for the plot of ground the town receives from the company 2.50 fl. per metre per year.

2⁰. The 7644 sq. metre space occupied by the firm of Scheuer Brothers, and by the Blauwhoedenveem. On his plot there is a warehouse with cellar, ground floor and from 3 to 5 upper floors of together 8800 sq. metres. The west end portion measuring 625 sq. m. is used for the Scheuer's Hull'line of steamers sailing every three days, whilst the east end is rented and occupied by the Blauwhoedenveem corporation for warehousing. For the ground space the town receives 2.50 fl. per sq. m. per year

To load goods from the warehouse into river boats moored in the inner basin along the south side of the quay two covered wooden gangways have been run out so that communication along the quay is unobstructed.

3°. A ground space of 869 sq. m. rented from the town and occupied by the Company which works the state railways; 2.50 fl. p. sq. m. per year is paid as rent for space occupied.

4°. The plot of 6950 sq. m. let also at 2.50 fl. per sq. m. per year to the Holland Steamship Company who in connection with the General Steam Navigation Company work the „Amsterdam—London"-line of Steamers running on alternate days. For the convenience of this trade the Company has built two sheds with 2500 sq. m. of floorage.

5°. To the Blauwhoedenveem corporation a second plot of 3475 sq. m. at 2.50 fl. per sq. m per year is let. On it stands a warehouse with cellaring, ground floor and four stories having 13,200 sq. m. of flooring. As in n°. 2° two covered gangways connect warehouse and inner basin.

6°. The 3475 sq. m. plot rented by the Vriesseveem corporation, also at 2.50 fl. per sq. m. per year, has on it a cellared warehouse also with ground flour and three stories totaling 11000 sq. m. of floor. Here again there are 2 connecting covered gangways between warehouse and inland basin.

7°. Three sheds which for their construction in 1891 cost the town 150.000 florins have an area of 5100 sq. m. The yard partitioned off for warehousing is 7500 sq m. The sheds and ground space pertaining thereto are let by the town to various independent regular lines. In the shed farthest east the Dutch South-African-Railway Company take at 3 fl. per sq. m. per year, 1000 sq. m. for the British Colonial Steam Navigation Company whose ships by an arrangement with the first named company run between Amsterdam and South Africa.

8°. On the east side of the last mentioned structure during 1894 the town is to erect a shed covering 3000 Km. for the use of the Ocean-Company, now using a part of the sheds mentioned under 7°. For this the quay wall along the Commercial Quay must be extended 95 m. The cost of the whole is estimated at 158.000 florins. The shed and adjoining space covering 4750 sq. m. are let to the company at an annual rent of 14.600 florins.

The quay is lighted by gas. Most of the Companies having buildings on the quay light them by electricity.

The lifts and other engines and appliances inside the warehouses are driven by town-supplied hydraulic power at 0.50 fl. per cubic mètre.

For the contingent prolongation of the quay for sea-going vessels a project, which is indicated by dotted lines on the plan, has been formed. The quays shewn will have berthing places off each side and are to be 107 m. wide. This width will be apportioned on each side of the centre line in this manner. Next to the dock a 9 m. width for two sets of rails and an overhead crane, then a 26 m. width for warehouses and sheds with platforms of 2 meters and 1 metre wide and finally a width of 18.5 m. on each side of the centre line or together 37 m., for ordinary and railway traffic.

(*b*) *Railway Dock.*

Constructed by Government in the Rietlanden in 1874 it has a length of 747 m., a width of 100 m. and a depth of 7.50 m. ÷ AP. It is used by ships putting out bulk cargoes such as minerals or taking in coal. Dock walls were built on each side and the enclosed quay space is 2.96 m. + AP. On the quay are laid a considerable number of sidings which are in communication with the Rietlanden railway system for manipulating traffic.

The rails on the north quay are worked by the „Holland Railway Company"; those on the south side by the Company which farms the State railways. River craft can reach this dock by the Diked-in-Y or by the new canal and the East Canal, whilst the entrance of the Rhine Canal is close to. Loading and unloading of ships is accomplished by means of steamcranes worked by the railway companies who own them.

(*c*) *Quais of the „Nieuwe Vaart*" (New Canal). The New Canal dock 900 m. long, 65 m. wide and 6.50 m. ÷ A.P. deep is used on the north, and on part of the south side for mooring sea going ships of small draught.

On the west end of the north quay, 304 m. long, the town has constructed a staging which, with a portion of quay space together 18,60 m. wide, and thus a superficial space of 5654 sq. m., is let to the Royal Netherland Steamship Company for a sum of 9620 florins per year. This company has 23 North Sea, Baltic und Mediterranean traders and on the space above mentioned has constructed an open shed and a closed one with the requisite cranes.

The 226 metre length of north quay farther east and adjoining the portion mentioned above, measuring 3810 sq. metres (for 190 metres its width is 18.60 m., and for 36.37 metres it is only 7.60 m. wide) is let for 6480 florins annualy, to the Holland Railway Company. This company owns the remaining east end of the quay, 270 metres long and reaching to the „Dageraadsbrug" („Aurora" or Daybreak-Bridge) adjoining the Company's railway goods station. This station includes two inland docks giving the greatest facilities for the loading into truck or ship of incoming or outgoing cargo. For loading and unloading into river craft especially the company has laid down hydraulic plant and built sheds on this quay. The plant named consists of a 20000 Kg. (21 tons) stationary crane, eight fixed 2000 Kg. (2 tons) cranes, two cranes equaly stationary, lifting respectively 350 and 750 Kg., and a movable one lifting 500 Kg.; — also a coal-loading lift and two capstans.

The east part of the southern bank of this basin is used as a goods station by the lessees of the State railways, who to amplify their available and self owned space rent from the town 12 ares ($1^1/_5$ acres $\underline{+}$) at a rentat of 450 florins a year. On it the company have constructed a staging and there can load and unload by means of their own steam cranes and winches. As a goods station and as a mooring basin for sea-going ships of small draught of water this dock and quay space is of very great value to the important Royal Netherland Steam Navigation Company. For larger merchantmen it is not suited. Moreover the railway bridge over the East dock locks and the Kattenburg bridge do interfere with its accessability.

The quays have excellent communication with the railway system. The lines on the north side are worked by the Holland Railway C^o^. who, as rent pay to the town 1.40 fl. per metre lenght of line laid on ground not their own or which is let to them. The lines on the south side are let to the lessees of the State railways.

The writer of this report is of opinion that a quay for the loading and unloading of large sea going vessels, such as now built, should fulfill these conditions:

It should have a width of 70 *metres if it be intended to berth ships along one side only, and of* 100 *metres when berthing is to be done on both sides.*

It should be in good communication with the Railway system.

It should be accessible to river boats requiring to use the cranes and lifts on the quay.

For a quay intended specially and mainly to put river embarcations in communication with the railways a width of 20 metres is sufficient.

(C.) Landing Stages and Jetties.

(*a.*) *The Large Commercial Jetties* (*Suez Piers*).

At the West Dock Quay (also called the West Commercial Quay) the town has constructed two deal-timber jetties, approachable by the largest draughted sea going vessels the North Sea Canal can accomodate or is accessible to. The cost was about 487000 florins making 35 fl. per sq. metre. They are let for 4200 fl. a year to the lessees of the State railways, who also work the West Dock Quay railways.

Each jetty is 120 metres long and 60 metres wide, and has its platform at a level of 2.50 m. + A.P. From one to the other is 75 metres.

As against the quays these jetties have the advantage of accomodating a greater number of ships. From centre to centre of these two stages is 135 metres. Two sea-boats can berth there, with stern quaywards whilst with the same quay length only one vessel could be moored against the quay.

As is here the case similar jetties should be accessible to the railway. Turn-tables as here used for running the trucks upon the stage but offer this double inconvenience that more time is consumed, and that the turn-tables are an obstacle to the ordinary quay traffic. Where the situation and available space allow of it, it is preferable to give a curve to the lines of rail and run sheer on to the stage or jetty.

River boats may reach the stages by the Diked-in-Y.

One of the jetties is used by the Netherland-America Steam Navigation Company, running alternately from Amsterdam and Rotterdam. The Company has put up sheds and steam hoisting apparatus. The other stage is used by the German East African line running from Hamburg and calling at Amsterdam.

(*b.*) *Cattle Landing Jetty.*

The stage used for landing cattle costs the town about 19000 florins, and is 104 metres long and 10 metres broad. It has an inclined platform, sloping from 2.50 m. in the middle down to 1 metre in order to facilitate loading and unloading at different levels. The necessary cattle sheds are constructed close at hand.

(*c.*) *Quay de Ruijter Jetties.*

On the north side of the three islands called „Stationseilanden" are 17 wooden jetties, constructed conjointly by the State and the town. All with the exception of two are intended for the use of steaming and other inland craft. The inland steamers serving Groningen, Hoorn, Alkmaar, Ymuiden, Purmerend, Nieuwediep, Monnikendam, Zwolle, Harlingen, Meppel and Arnhem regularly, have their mooring places there.

The jetties for the inland steaming and other craft are from 25 to 40 metres long and 5 metres wide, and afford mooring on both sides. Their cost was about 30 florins per metre. No hoists are is provided on them for loading or unloading purposes; the craft use such tackle as they possess on board. These wooden jetties have no railway communication. But they are, by those interested, greatly appreciated on account of their convenient situation and easy accessability.

On the east side there is a landing stage or jetty which is let to the Royal West Indian Packet Company for 2950 florins; this Company has a service of boats running every three weeks to the Dutch West Indian Colonies and New York. The jetty here in question is 70 metres long and 25 metres broad, and has a shed erected on it. Loading and unloading is accomplished by the ship's own hoisting apparatus. There is no railway connection and this is found inconvenient.

To the east of the last one there is another jetty used by a service of vessels running weekly to Leith and other Scotch ports.

(*d.*) *Jetties, Quays and Wharves in different parts of the town for Inland traffic:*

Fronting the open port, along the Damrak and other canals some jetties have been constructed for the use of river craft inland, but these are similar to those on the de Ruyter quay and need no special description.

These jetties as well as the numerous quay walls along the canals within the town, are intended for river boats which never or rarely have connection with sea going ships or with the railway, but simply bring the daily supply of provisions for the 445000 inhabitants of the town.

These craft have no particular requirements as to wharfage and depth of water. The essential is that these are centrally and conveniently situated.

> „*With regard to jetties intended to be used by sea-going vessels we* „*would express the wish to see them suitably connected with the railway* „*systems and made accessible to craft using the inland waterways.*"

D. Timber Quay.

The Timber Quay, built by the town in 1879—83, at a cost of 1 600 000 florins has docks and basins measuring about 73 hectares, whilst its warehouses have an area of 53 hectares.

To prevent the forming of waves and to secure still water this quay has been shut off from the Y by an earthen dam.

Beginning on the south side this harbour has:

1º A basin for rafts of about 14 hectares, with a depth of 2.5 m. ÷ AP., adjoining the above named basin *A*, *a*, and divided into several parts by wooden partitions.

2º On the South West, adjacent to this basin and communicating with it are 10 small basins each 135 m. long, 20 m. wide, and 2.5 m. ÷ AP. Between these basins are sheds, which are let to dealers in sawn timber.

3º On the north side of the basin mentioned in 1º are two other basins for rafts, one of about 5 hectares and another of about 9 hectares, the depth of each being 2.50 m. ÷ AP.

4º A basin for sea-going vessels, measuring 13 hectares, 6.50 m. ÷ AP. and another basin (called „*Minerva*") 21 hectares in area and 7.50 m. ÷ AP.

5º A canal deep 2.5 m. ÷ AP. putting these last named basins in communication with the basin for rafts.

On the west side of the „Minerva" basin during 1891 the town executed different works costing 100,000 florins. This part of the basin has been put in communication with the railway system and is intended for the Rhine transit trade. The work referred to consists of the construction of: 3 basins each 75 by 30 m., and 3.5 m. ÷ AP. a depth sufficiently great for Rhine boats; 2 sheds together comprising an area of 3200 sq. m. for warehousing purposes, or if need be for handling and sorting wood in transit; and finally 4 sheds of 1560 sq. m. for storing wood. This work is simply a trial and may, if found requisite, be considerably extended northwards.

The timber quay is, as far as is requisite, in communication with the railway system. The ground work for the connecting line, which has been prolonged as far as the petroleum basin, was constructed and laid by the town for 90,000 florins. The Dutch Railway C°. built the railway and undertook the management and working of the line, and by way of a rent agreed to pay 1 florin per ten ton loaded truck run upon it.

To the above basins access is afforded to sea-going ships by an opening of 30 m. in width in the dam which separates the timber harbour from the Y. The smaller vessels for inland navigation can enter the port by the west channel or from the Yside. No special works have been provided by the town for loading or unloading wood, as the need for them has as yet not been felt. Ocean going ships having cargoes of wood for transshipment into river boats, or which are putting out timber for further conveyance in rafts, generally prefer mooring to the bollards in the two large basins. When planks and deals are to be delivered on shore, the ship is moored alongside, and by means of rollers the deals are pushed ashore.

Wood is imported especially from Russia, Sweden, Norway, the German Baltic ports and America. The amount brought to Amsterdam was in 1890 176000 cub.m.; in 1891 177622 cub.m.; und in 1892 226887 cub.m. The number of timber-laden ships entering Amsterdam port was in 1890, 1891 and 1892 respectively 282, 243 and 276.

The warehouses on the timber quay are let at about 0.30 fl. per square metre per year. Ten hectares more or less are thus let to different timber merchants. If required by them, a certain water space in the timber basin may also be rented, and in this way at least 18 hectares at 0.025 fl. to 0,04 fl. per sq.m. of water surface are taken.

Of the structures for commercial transit needs on the west side of the „Minerva" basin the two sheds alongside the shore are let for 2200 fl. a year; and two of the four situated behind these are let together with an open ground space for 1400 florins.

For storing wood in the unlet part of the timber basin 0.01 fl. per month per sq.metre is charged.

E. The Petroleum Basin.

On the south shore of the North Sea Canal near the west end of the town and about 1600 metres from the entrance to the timber basin, the town constructed, between 1887 and 90, a petroleum basin. It is horse-shoe shaped and has two entrances; each of these entrances is 31 metres wide and can be shut by iron floating beams. The object aimed at in making a second entrance was a choice of exits in case of fire for ships seeking security.

The measurements of this basin are 911 m. by 171 m., with a depth of 8.20 m. ÷ AP. and a superficial area of $15^1/_2$ hectares. The open ground space pertaining thereto measures 12 hectares, is situated at a level of 1 m. + AP.

Mooring posts, 120 m. apart, are fixed along the wharf, and between the shore and each berthing station movable guides keep the ship 10 metres out from the shore, and allow of river craft coming between ship and shore if desired.

No special loading and unloading apparatus is provided. Barrels are rolled along sloping platforms or gangways. Tank-boats use their own gear for taking in or unloading petroleum; if needed steam can be supplied by the boilers on the warf.

Without reckoning expense of laying down the connecting railway and cost of land, 350 000 florins have been spent on this basin.

On the north side the Amsterdam Petroleum Harbour Company has 3 hectares of the ground space, on which they have put down 5 iron tanks to contain together 105 000 barrels of petroleum; a storage and barrelling shed; an underground storing place for filled barrels which comprises an area of about 1000 square metres; also offices, storehouses, work-shops and jetties for the inland navigation craft.

The boiler house for supplying steam to the Worthington pumps is at some distance, and cannot therefore be a source of danger.

Between the town and the Company a contract has been entered into, in which it is stipulated: That the Company may store and manipulate petroleum and other inflammable commodities for other parties only and may not traffic therein on their own account.

The maximum tariff to be charged for services rendered is to be fixed by the town. The Compagny is to provide and maintain its own necessary manipulating apparatus.

The town shall receive as rent 6000 fl. a year, and half the surplus after 6 % has been paid to the shareholders.

About 1.80 hectares on the south side of the basin is let to the American Petroleum Company for 7340 florins per year. This company has put down 3 tanks to contain a total of 72000 barrels: also the necessary storage and warehousing and jetties for loading and unloading inland river craft; also an engine-house has been erected at a suitable distance.

The Amsterdam petroleum imports were in 1891 309626, and in 1892 507800 barrels.

F. Bonded-Warehouses.

The Custom House Dock was made in 1827. It is 850 metres long, and on an average 66 metres wide, and has open ground space, warehouses etc. on each side. It no longer answers however the present requirements, and for sea-vessels is accessible only by the Custom House Dock locks whose width is 13.70 m., and the sill at 5.80 m. ÷ AP.

This entrance is unsatisfactory, not only on account of its insufficient depth, but also because of the obstruction and loss of time in passing through the East Dock locks, the Kattenberg bridge and the Canal.

Only exceptionnally therefore do sea-going vessels moor in this dock. They stay in the Y or the East Dock and goods for the Custom House Dock are put on flats or barges, which convey them thither.

In the dock itself work is not interfered with or inspected by the customs officials. The goods are treated and looked upon as if still in a foreign port, and only the entrances to the warehouses used by the public, are watched.

The warehouses and sheds number about 120 and together afford 140000 sq. metres of storage space. Of this $^{2}/_{5}$, or about 5600 sq.m., are generally given up to free goods, especially coffee, rice, cotton, corn, skins, tin, cinchina-bark etc. The remaining $^{3}/_{5}$ about 84000 sq. mètres, are used for duty paying imports such as sugar, tobacco, wines, spirits, tea, currants, salt, spices etc.

The cellars are ordinarily used for wines and spirits. For a whole floor the charges are, per mouth and per square metre: For cellar, ground-floor or first floor 0.17 fl.; for 2nd floor 0.15 fl.; for 3n floor 0.12 fl.; for 4th floor 0.10 fl, and for the 5th floor 0.06 fl. For providing labourers and for weighing etc., the charges are very moderate.

Except two 1500 Kg. steam cranes there are no rapid loading and unloading appliances with a fixed scale of charges.

Although this dock is in communication with the railway system, and is very accessible to inland river craft, it must either be abandoned or turned to some other purpose.

Plans for a dock answering all requirements and capable of receiving sea-going vessels are ready. This dock is to be in the „Stads Rietlanden" on the south side of the railway basin already described.

G. Floating Docks.

The „Amsterdamsche Droogdokmaatschappij" owns and works the following docks:

1⁰ The Koninginnedok" (Queen's Dock) on the North side of the Y opposite to the East commercial quay with a length of 122 metres, a breadth of 26 metres, and a depth of 5.25 metres.

The lifting power is 400 000 Kg. By means of four steam engines and centrifugal pumps this dock can be emptied and the ship be raised in 1³/₄ hours.

In the neighbourhood and close to are workshops and repairing yards: — viz.

A smithy with large and small steam hammers.

A turning shop with the necessary tools for making different pieces and parts requisite for steam ships up to 3000 horse power.

A boiler-maker's shop with hydraulic plant for bending and shaping brass tubes of large diameter.

An iron and metal foundry, with a 5000 Kg. movable crane.

In the engine houses are three horizontal boilers with a total heating surface of 84 sq. m. and two 40 horse power horizontal engines, one of which drives the electric dynamo for lighting purposes (120 fixed lamps and 14 movable lights.

The other buildings consist of warehouses, model making and building shops, offices and 12 dwelling houses for employés and workmen.

Close to this dock is a screw dock with a lifting power of 4000 Kg. and a depth of 2.75 m. for repairing screws and shafts of inland steam-craft.

2⁰ The Koningsdok (King's Dock) on the north west side of the town is 122 metres long, 22 metres wide and 5.10 metres deep. The lifting power is 3 000 000 Kg. The dock is in four parts and may be used as one whole or separately. Near this dock are also large and spacious workshops where every possible kind of repairing work is done. There is a 4000 Kg. movable crane.

During the 15 years' existence of the company there have been repaired or refitted by them 2730 vessels with a total tonnage of 3 122 235 tons. The number of days and of docks worked during this period has been 7575.

Harbour Dues.

All sea going ships and inland craft entering the town's port and canals are subjected to dues as follows:

a. Sea-going ships.

1° All such, with the exception of those mentioned under 2°, 3° and 4°, pay:

Sailingships	0.06 fl. per cub. metre.
Steamers	0.0425 » » » »

2° Sea-going vessels, timber laden or for the herring-trade:

Sailingships	0.04 fl. per cub. metre
Steamers	0.03 » » » »

3° Sea-going vessels, with coal, coke or pig iron:

Sailingships	0.035 fl. per cub.m.
Steamers . . . . ,	0.025 » » »

4° Sea going vessels, laden with iron ore:

Sailingships	0.025 fl. per cub.m.
Steamers	0.0175 » » »

Ships with mixed cargo are taxed at the rate under which the greatest bulk of their cargo falls.

When a ship both arrives and leaves empty the dues are refunded.

b. Inland and River Craft.

1° All such craft, with the exeption of those mentioned under 2° and 3° pay:

For each voyage, per cubic metre	0.025 fl.
With a minimum charge per boat of	0.10 »

2° Craft intended for use exclusively or principally within the town limits: a single yearly payement of:

For steamers	0.80 fl. per cub.m.
» craft other than steamers	0.40 » » »
With a minimum per boat of	1.50

3° Craft sailing at regular times and having a fixed mooring place, a fixed yearly rental payable in one sum for the whole year:

Steamers running regularly not more than 7 times per week	0.60 fl. per cub.m.
Steamers making more than 7 runs per week	0.80 » » »
Boats not being steamers	0.10 » » »
With a minimum of	1.00 »
Craft without motive power and not exceeding 40 cub.m., and used for bringing cargo into the Y, but not making use of the town's loading and unloadung appliances unless specially paid for each time used, a single yearly payment of . . .	0.30 » » »
With a minimum of	1.20 »

The rates mentioned under *b*, are augmented by a third for ships belonging to companies carrying passengers and having special landing stages.

The Rhine craft plying regularly between Amsterdam and the Rhine are not subjected to this augmentation.

When a Rhine boat both arrives and leaves empty the dues paid by her are refunded. Also when a Rhine craft arrives loaded but leaves empty, or arrives empty but takes away cargo, half the amount of dues paid are refunded to her.

Harbour dues are calculated:

For sea-going vessels on the gross tonnage, as given by the government certificate or otherwise as per the foreign measurement if this frees the ship from registering here.

For river craft and other boats engaged on inland waters the dues are calculated according to the government certificate.

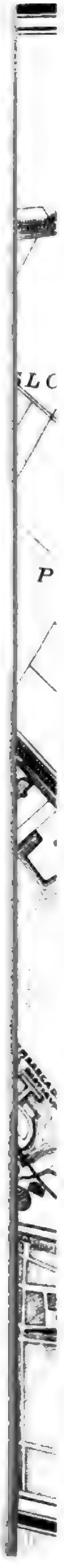
The tonnage of craft unprovided with any of the above named papers is estimated and tariffed by the Collecter of Harbour Dues.

For craft plying exclusively and principally within town limits single annual payment system is enforced, for inland canal and river craft with regular runnings and with special mooring places assigned to them it is allowed to pay once a year.

Upon all sea-going ships remaining in the port more than 3 months, a charge of one fourth of the port dues is made for each month entered upon, up to a maximum of 0.01 fl. per cubic metre for sailing ships, and of 0.0075 fl. for steamers.

For inland craft whose port dues are not paid yearly these dues fall anew to their charge for each month begun after their first month's stay in the port. Nevertheless in the application of this rule allowance will be made for the time covered by payments made as trading or market dues.

(Translated by Wm. H. Harwood, Brussels.)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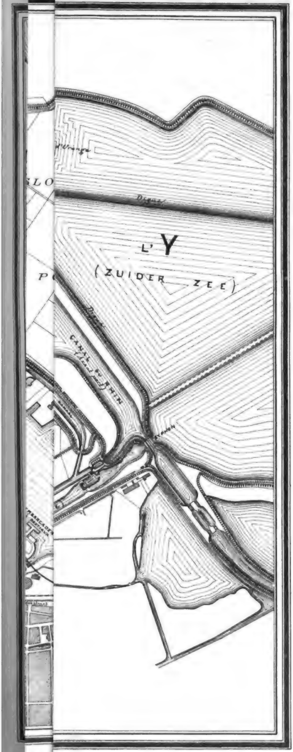

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VIth INTERNATIONAL INLAND NAVIGATION CONGRESS
THE HAGUE 1894.

3nd QUESTION.

MEANS FOR PREVENTING ICE BLOCKADES

BY

M. GEORGES NARTEN,
Königl. Preussischer Wasser-Bauinspector at Harbourg on the Elbe.

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MEANS FOR PREVENTING ICE BLOCKADES

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Until the last few years the stoppage of navigation by frost was considered as an evil without remedy.

Latterly however efforts have been made on all sides, even at great sacrifice on sea-water canals, the mouths of rivers and in ports to prevent this stoppage or at least to shorten its duration.

It is therefore very important to be acquainted with the results of these efforts and the means employed to attain the object in view.

We will give some account of these in the present report in the following order:

Different systems and methods for breaking and clearing away ice; ice breaking boats; explosives etc.; results; cost of necessary plant; working expenses.

I. — GENERAL OBSERVATIONS.

It is in the first place necessary to know why the removal of the ice on a river is necessary; whether it is solely in the interest of navigation, or in the interest of navigation and rural economy combined, or in the interest of the dams and low lands protected by them.

From the experiments made up to the present time, it is proved that for the maintenance of maritime navigation it is necessary to remove the covering of ice from the surface of the stream as soon as it is formed and boats can no longer themselves do it in their course or their passage is rendered more difficult.

The covering of ice must necessarily remain on the river above the limits of navigation, in order that the broken pieces of ice in the upper river may be prevented from coming down; this is a measure which contributes to maintain the channel free for navigation.

Generally the breaking of the ice above the limits of maritime navigation should not be commenced until a thaw may be expected.

However, when the thaw has already begun in the upper basin of the river, while the frost continues in the lower basin, if we would regard the safety of the dams and avoid disastrous floods, we must not wait until the thaw has also declared itself in the lower basin, but energetic means should be taken to clear the stream above the limits of maritime navigation. These operations, it is true, will be useless unless the blocks of ice that have been detached are able to descend to the lower basin.

The Council of the town of Hamburg since 1874 (at first with a single ice-breaking steamboat), regarding only the interest of maritime navigation, took upon itself to prevent as far as possible the formation of thick ice on the Lower Elbe below the town and to clear away the broken ice *in spite of the slackened current.*

Ice-breaking boats were used only after this date upon the Upper Elbe; in fact only after the disasters of the winter of 1887—88. During this winter the formation of ice-floes and the swollen condition of the Upper Elbe caused the greatest havoc to the dams and low lands which should have been protected by these dams.

2. — VARIOUS SYSTEMS AND METHODS FOR BREAKING AND CLEARING AWAY ICE.

According to the experiments made on the Elbe there are no other means to recommend for keeping the channel free in time of frost but ice-breaking steamboats.

It is a fact that other experiments have been made on the Elbe by the army, which has used explosives (powder and dynamite), but these experiments have had no very marked results; in fact by reason of the masses of fragments formed they have been almost without result.

When the ice is very compact and thick and the water is *tolerably deep*, mines placed as deep as possible may shatter a large area of ice and by that means facilitate in some degree the work of the ice-breaker.

It is true that when the ice presents a united surface, large stretches can be dislodged by numerous explosions systematically organised; but this operation is very slow and the expense is great.

For the portion of rivers affected by the tide, this latter method employed without the co-operation of ice-breakers has few advantages.

The blocks of ice detached by blasting will descend a little way with the ebbing tide, but will return with the flood and mix with the floes from up stream or with the mass of ice which covers the stream higher up; they will slide one on to another and freeze into one solid mass.

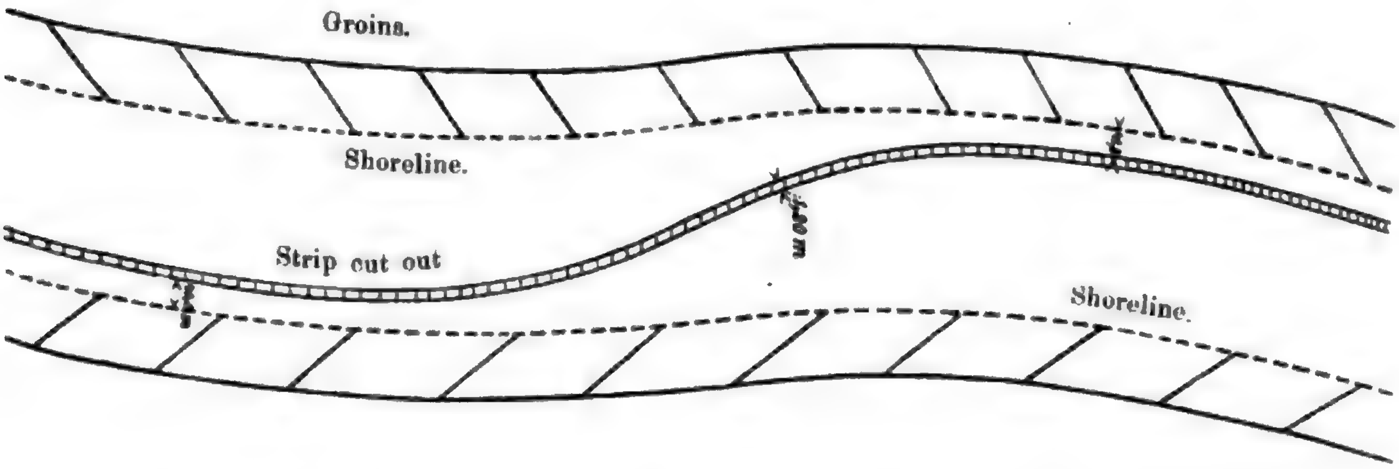
It is then necessary to repeat the blasting, and the more floes of ice are formed the less will be the effect of these explosions.

Experience has shown that without the help of ice breakers it is useless, or almost so, to have recourse to explosives and that blasting does not even render great assistance to the ice breaking boats.

Explosions are only effective in detaching the ice in certain isolated spots which are out of the reach of the ice-breakers.

Besides explosions it has been attempted to saw through the coating of ice. The object of this operation was to facilitate the spontaneous breaking of the ice as well as the working of the ice-breakers.

During the winter of 1890—91 the ice covering the Upper Elbe was sawn through from Elbstorf to Geesthacht (*station* (*) 590 to 584), i. e. for a distance of 6 Km. The average thickness of the ice was 0.75 m. A strip of ice 1.20 wide was sawn away. After this was carried away a channel was formed in the middle of the current at a distance of about 40 m. from the groin heads. This operation occupied much time and was very expensive. It certainly, as has been affirmed, allowed steamers to advance more easily, but the experiment cannot be recommended; first on account of the time it requires — it takes time before the strip can be sawn away and divided into pieces by means of axes and removed from the channel — also on account of the increased expense, and moreover because the slight advantage obtained is lost again directly the frost becomes settled and the channel closes up.



In most cases the sawing cannot be commenced at just the right moment.

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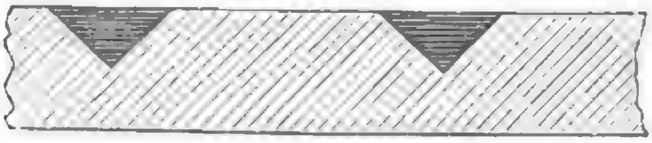
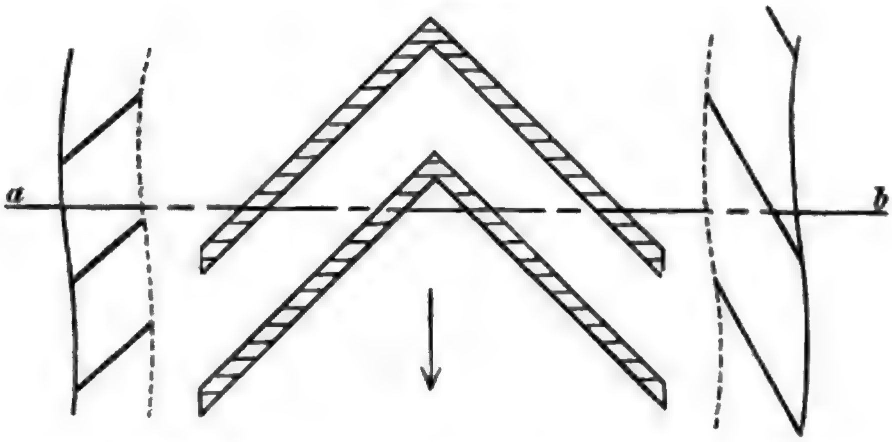
(1) Marks or «mile stones »are placed at a distance of 1 m. apart along the navigable portion of the river. They are known as *stations* and are generally numbered. - - Trans.

It is not possible to make gaps in the ice ahead of the ice-breakers, the work of the latter being too rapid, they quickly overtake the place where the hand labour has got to.

Section through *a b.*



Grooves.



After these experiments it has been attempted to diminish the resistance of the ice by making grooves in it. But this method has also been without succes.

3. RESULTS.

Since the winter of 1892—93 the Hamburg Administration, as well as the Prussian Administration of Works on the Elbe, are so well provided with ice-breaking boats that, except for an altogether abnormally low water-level, they are both able to ensure the removal of the ice both on the Upper and Lower Elbe.

For the clearing of the ice from the Northern Elbe, from the port of Hamburg and the Lower Elbe, the Hamburg Administration, as has already been said, has had in use since 1892 seven ice-breaking boats.

The three smallest, „Simson", „Hofe" and „Move", are used for clearing away the ice from the Northern Elbe and the port of Hamburg (Cf. annexed table).

The removal of the ice from the Lower Elbe below Hamburg as for as Glückstadt is effected by four larger ice-breakers, „Ice-breaker I", „Ice-breaker II", „Ice-breaker III" and the „Elbe". It is not necessary to break the ice further than Glückstadt, because below this station the ebb and flood are so strong and the current of the river so violent that the ice does not stick.

The subjoined plan of the steamer „Hofe" gives an idea of the smallest Hamburg ice-breakers; the plan of the steamer „Elbe" shows the nature of the largest in use.

The Hamburg Administration proved during the long winter of 1892—93, in spite of the lowness of the water, that it is able by means of its ice-breakers to ensure navigation in its port and on the Lower Elbe.

On the Upper Elbe, where in 1887—88 masses of ice had done much damage, the breaking of the ice had become a necessity. Not yet having any ice-breaker, tugs had to be hired for this purpose.

This expedient was ineffectual and incurred heavy expenses; the hulls of these boats not being sufficiently strong, their repairs were too extensive; besides the screws and shafts were incessantly damaged or broken, for these parts of the boats were not built with a view to the service now required of them.

The Prussian Administration of Works on the Elbe soon recognised the necessity of having boats of their own built specially for breaking ice, and during the winter of 1889—90 three steamers of this kind were at work, viz.: the „Wal", the „Robbe" and the „Delphin".

In the following year the ice-breaker „Lüneburg" was added to this number.

It was found however during the winter of 1890—91 that in very severe winters these four boats were not enough to keep the river Elbe free between Hamburg and Altona, and above Harbourg.

It was absolutely necessary in order to keep the river clear behind and to provide for the return of the ice-breakers, even to hire a few tugs. Only these latter, on account of the continual repairs which we have mentioned were not sufficient; so that the Prussian Administration of Works ont he Elbe decided to increase the number of ice-breakers.

During the winter of 1892—93 the Prussian Administration maintained on the Upper Elbe seven ice-breakers and two steam launches strongly built for the same purpose. These ice-breakers, besides the four mentioned above, were the „Eisbär", the „Walross" and the „Widdes" and the two launches the „Molch" and the „Salamander".

The annexed cuts give a plan of their construction.

At present in the basin of the Upper Elbe provision is made against the disasters that may be met with from ice-floes, as was proved during the winter of 1892—93, even in spite of the extremely low level of the water.

Ice-breakers can only work to advantage against the current, and it is important in that part of the river that is affected by the tide to begin breaking the ice as soon as the tide goes out, so that with the ebb the floating fragments may be carried so far away that they will not re-enter the river with the next tide.

After breaking the ice — the most important thing — care must always be taken to observe that the part between the ice-breaker and the sea remains free.

The Hamburg ice-breakers are consequently distributed on the Lower Elbe in such a manner that ice-breaker no. III devotes its attentions to keeping the river open below Pagensand as far as the sea; ice breakers I and II from Finkenwärder to Pagensand, and ice-breaker the „Elbe" from Hamburg to Finkenwärder.

The ice-breakers are at work continually during the frost and aided by sea-craft coming in and out, they are therefore always in a position to keep the passage open.

The clearing away of the ice on the Upper Elbe is done differently.

At is not attempted to break the ice on the Upper Elbe above Harbourg (in every case first of the portion affected by the tide) until there is some hope of obtaining good results or it becomes an absolute necessity.

Five ice-breakers are employed according to the nature of the ice.

These boats placed abreast so far as the width of the channel will allow it attack the ice all at the same time; the latter is broken up over a width of more than 200 m. and the broken pieces float down to the sea.

If the channel is not wide enough only two or three boats attack the ice; the remaining ice-breakers then endeavour to break the ice still adhering to the sides by the violence of the waves which they cause by passing and repassing at full steam. Two other steamboats take care that the part freed of ice remains open.

These two boats placed down stream are intended to make the broken pieces of ice follow the current without delay; they should break off and cause to float away the pieces of ice in the hollows between the groins or on the sand, so that a compact mass may not form below the ice-breakers at work. This in fact might seriously affect their action, and besides, these two boats themselves, covered with ice above and below, might run the danger of being damaged by the masses of ice coming down stream.

They therefore must be constantly in communication with the ice-breakers properly so called and the lower freed portion of the river, and consequently never cease to move night and day.

Up to the limit where the tide is felt not more ice should be broken than the tide is able to carry away (i. e. 2 or 3 km.). Otherwise the broken ice coming back with the rising tide would render ineffectual all the work that has been done.

Moreover it is of the highest importance to get rid of the ice *right across the stream*, in order to obtain as wide a passage as possible.

To facilitate matters after the channel has been opened a few boats should pass up and down at full steam; by the motion of the water they will in this manner succeed in loosening the ice from the slanting banks and shore. This system has given the best results.

During the winter of 1892—93 the Prussian ice-breakers penetrated as far as *station* 436 (Cf. annexed plan), i. e. about 5 km. below the mouth of the Havel. Above *station* 436 the ice was already in movement.

A coating of ice therefore of a total length of 189 km. was dislodged above Altona.

The clearing away of ice this winter lasted from the end of December to the middle of February.

By this means the serious injury which might have been sustained by the bank from the ice-floes was avoided and the navigation of the Upper Elbe was free at least three or four weeks earlier than it would have been without the aid of the ice-breakers.

The Prussian Administration of Works on the Elbe every year at Harbourg on the 1st December prepares all its ice-breakers for the clearing away of ice; and they are reserved for this service until 1st April.

The Hamburg ice-breakers I, II an III, as well as the Prussian ice-breakers „Eisbär", „Walross" and „Wal" are only used in time of frost. In summer they are not used, because experience shows that the use of large ice-breakers for towing is not practicable, both on account of their large consumption of fuel and the expense of working them.

On the contrary, the ice-breaker „Elbe" is used in summer as an inspecting boat on the Lower Elbe, and is also employed for placing buoys and other work.

The other three Hamburg steamers, „Simson", „Hope", and „Möve", as well as the Prussian ice-breakers „Lüneburg", „Robbe", „Delphin", „Widder", „Molch" and „Salamander" (for the Hamburg and Prussion Administrations of Works on the Elbe leave the work of dredging in the hands of trustees) are used for the removal of the earth brought up.

The Hamburg steamers are all built in the form of ramming boats. On the other hand the Prussian Administration is in possession of two kinds of ice-breakers, viz:

a. Grounding boats.

These are to be recommended where large stretches of rotten ice or hard strong ice have to be removed, provided it is not frozen to the bottom of the bed.

Preference should be given to a flat keel so that while attacking the ice the boat may remain horizontal as much as possible.

A curved bottom is effective for keeping a straight line of navigation, but it may help to hamper the vessel among the ice.

It has been attempted to *concentrate the weight in the bows* and make *keels of a particular form* in order that the ice may the more easily be broken. But the experiment has not been a success even in firm hard ice, on account the elasticity of the latter. Double keels like those used for the ice-breakers on the Vistula have been found equally dangerous.

The use of the keels for breaking porous ice is absolutely without result. Steamers with double keels become wedged in attacking the notten ice and the help of other steamers is nearly always required to rescue them from their position.

The steamer works in the ice in a comparatively quiet manner when, without displacing her waterline (or centre of gravity), she can run on and skid off the ice so as to find as far as possible the places which offer the least resistance.

The prow of the grounding ice-breakers of the Prussian Administration rises 0.6 m. above the water and slants away at an angle of 17° until it joins the keel at a slight curve 1 m. in front of the middle of the vessel. With this normal water-line the draught amid-ships is 0.25 m. less than at the stern.

By increasing the draught aft the angle is increased without, however, interfering with the working qualities of the boat; on the contrary it is more difficult for the prow to break trough the ice when on a level with the water.

Allowance being made for the loss of effect caused by the shock, it is affirmed that to facilitate the operation of grounding an appreciable elevation of the bow of the boat is necessary.

b. Ramming boats.

These work well in ice-floes when masses of ice have to be broken and cut into pieces. They also must have their bows out of the water when attacking the ice. The centre of gravity therefore should be rather aft of the middle and the boat should be built heavier in the stern than in the stem. It is well in order to give it more cutting power to construct it on sharp lines.

Arrangements specially designed for increasing the effect, as for instance the use of ice-ploughs on the bow of the boat, have not given the results anticipated. On the contrary the vessel works all the better for not having its movements hampered by such apparatus.

These boats only admit of constant work when the ice is comparatively thin, or in ports. Here they surpass other kinds because they can go easily astern in a straight line, which the grounding boats cannot do. The steersman therefore of the ramming boats in consequence of their great facility in this movement is able more easily to avoid collisions with other boats lying in the port.

The grounding boats, it is true, are easily manipulated going straight ahead, as we said above, but it is no longer so in moving stern first.

If these is no room for turning the boat completely round, the steersman can only make her go astern by keeping along the ice.

In order to be able to loosen the ice on the river and to get rid of the ice-floes the Prussian Administration of Works on the Elbe has adopted both sorts of ice-breaking boats for service on the Upper-Elbe between Altona and Harbourg, viz. five grounding boats (Eisbär, Walross, Wal, Robbe and Delphin) and two ramming boats (Lüneburg and Widder).

So far experience has gone to show that this proportion of five to two is good. The two steam launches „Molch" and „Salamander" are also built in the form of ramming boats. They are especially used in shallow waters and in the ports of the Upper Elbe.

The following is the manner in which ice-breakers generally work among strong ice mixed with slush: they take a run of 100 or 200 m. and throw themselves upon the ice, *breaking by their weight*, and keep on until the force acquired is exhausted.

The steamer then stops and retires to the requisite distance to take another run for the next attack. This takes place at some distance from the first. In this manner a wide channel is obtained from the first and the pieces floating away from the breach made by the first attack are thus avoided.

Under ordinary conditions grounding boats according to the thickness of the ice slide on to the surface for a distance equal to one and a half times the length of the boat and break it by their weight. The results of ramming boats on the contrary are less considerable; they cut into the ice only half their length or their full length.

It not infrequently happens that a boat remains with her prow resting on the ice and finds herself unable to move. In this case a second ice-breaker has to come to her assistance. The latter throws herself against the ice as near to the first as possible and breaks the ice which grips her. If that is not sufficient she hauls the captive boat away by means of a cable.

As soon as a narrow channel has thus been made through the ice, the boat effects the removal to the fragments by going up and down the channel at full steam. The movement thus produced in the water is sufficient to dislodge the ice still adhering to the sides and to draw them into the current.

4. NUMBER OF SCREWS.

When the draft is sufficient (about 1.50 m.) preference should be given to boats with single screws.

These run less risk of striking the ice; the construction of the engines will be less complicated and if the screw is large enough it will produce a sufficient propelling force and the effect desired.

If the boat is full by the stern, the screw is in less danger from floating blocks of ice, but its action will be less effective.

It is therefore a mistake to endeavour to lessen the possibility of accident to the screws and shaft by altering the form of the boat.

The screw and the shaft should be made as strong as possible and of the best metal; it is also desirable to fit a safety coupling in front of the sternpost, in order to avoid accidents to the engine while making its greatest efforts. It is useless for the sake of safety to supply the shaft with double bearings in the stern, because a bending of the rudderpost might easily interfere with the working of the boat and that part of the stern itself is not fit for the support of the bearings. Boats with two screws are very useful and at times absolutely necessary, as for instance when with a small draught great power and easy movement are required. The use of safety couplings is also to be recommended, and the shaft and blades of the screw should be of powerful construction.

The cost of building and working steamers with double screws is also considerably greater than that of single screw boats.

5. CONSTRUCTION OF THE HULL.

It is important to strengthen the boat with a sufficient number of horizontal beams so that the skin alone shall not have to withstand the violence of the shocks produced.

The largest ice-breakers have three keelsons (or carlings), two ram-cheeks at the water-line and one powerful deck-cheek.

A good assortment of these different longitudinal supports in the bow of the vessel is useful to distribute the effect of shocks as much as possible. The frames in the bow of the boat should be brought nearer together (about 25 cm.); or else additional frames in the form of girders should be inserted between the frames in order to prevent as far as possible the crushing of the hull.

The plating at the water-line and along the keel should be 13 mm. thick. The other plates and strakes may be weaker (6 or 8 mm.).

Soft steel is preferable to forged iron for the plating. The tensile strength should not be more than 45 kg. per sq. mm., that the plates may not break along the line of rivets.

For smaller ice-breakers it has been found successful in giving the hull the requisite stiffness to place inside pieces of wood 10 or 15 cm. thick 10 cm. above and 30 cm. below the water-line.

6. ARRANGEMENT AND FITTING OUT OF THE ENGINE.

The engines of ice-breakers are generally like those of screw tugs; only the greatest precaution should be taken to see that they are firmly fixed.

In spite of the great consumption of steam it is well to neglect the condensation of it.

Experience has shown that in notten ice the feeding pipes of the pumps easily become choked. The means ordinarily employed in these cases, such as jets of steam, reservoirs where the hot water resulting from the condensation of steam is collected, are absolutely without effect. Even by letting the feeding pipe end in the neighbourhood of the screw, where there is always open water, no satisfactory results have been obtained, for the pipe is easily obstructed by sand and frost.

The exhaust steam is better utilised for the production of artificial draught for the boiler. In this manner the greater consumption of steam is partly compensated for by the more energetic action of the engine.

The trials with the „Eisbär", „Wallross" and „Widder", the last three ice-breakers acquired by the Prussian Administration of Works on the Elbe, which have no condensing apparatus, have given really far more satisfactory results.

The derangement caused by the non-working of the pumps is avoided, the cost of fuel, it is true, becomes a little greater, but on the other hand the expense of repairing the engines is sensibly reduced.

In every case it is always necessary to have in the engine-room reservoirs large enough to ensure at all times a sufficient supply of water to feed the engines. In the same way it is useful to connect this reservoir with the tanks in the stem and stern of the vessel that needless trouble in working may be avoided.

Also steam pumps sufficiently large to clear the different compartments of the boat, as well as to fill the ballast troughs, are indispensable.

Electric lamps (of about 30 *ampères*) are very useful for exploring the ice, banks etc.

The breaking of the ice properly so called is however accomplished at night with difficulty by electric light.

The lighting by steamers placed astern of the ice-breakers at work, which only one or at most two steamers can manage, is not sufficient when extensive fields of ice have to be dislodged, as in this case the ice-breakers have to make rapid backward movements.

Ice-breaking boats cannot work by their own light while attacking the ice; partly because collisions would be inevitable on account of the different effects of light, and partly because, as experience has shown, the steersman is blinded by the light of his own vessel which must be in front of him. Boatmen also work more willingly without electric light.

7. TANKS.

Tanks of water at the stem and stern of the boat have been found very effective in changing expeditiously the position of the water-line.

The attempt to replace the water ballast by chains has not been successful, the apparatus working with too much difficulty. Moreover, in cases of necessity, in shallow water, it is difficult and even impossible to remove the chains.

Nevertheless it will be necessary to heat the water in the tanks by means of steam pipes to guard against the frost.

8. EQUIPMENT OF BOATS.

Solid bulwarks connected directly with the hull are preferable to railings in the form of a balustrade, because the deck is thus better protected from frost and the resisting power is really greater.

No deck cabins should be close to the bulwarks. Ice launches (supplementary launches) with flat bottoms are preferable to launches with keels, because they can be moved on the surface of the ice. However, care should be taken that they are easy of manipulation and suspension on davits by means of running tackle. It also necessary to protect the ship's sides by heavy gunwales it is effective to provide the stem and the stern with large and strong fenders of tarred Manila hemp.

There is room in the ice-breaker for quarters for the master, the engineer and the crew.

The largest ice-breakers also have a sleeping berth and a room for the engineer who directs the movements.

9. OUTLAY NECESSARY.

The original cost of the ice-breakers of the Prussian Administration amounted to 438500 marks. That of the Hamburg ice-breakers, which are much more strongly built, amounted to 1564000 marks.

The cost of each ice-breaker, the year of its construction, the respective dimensions of the boats, boilers, engines, consumption of fuel etc. are indicated:

a. For the ice-breakers of the Prussian Administration of Works on the Elbe in annex *A*;

b. For the ice-breakers of the Hamburg Administrations of Works on the Elbe in annex *B*.

10. WORKING EXPENSES.

The working expenses of these steamers incurred exclusively in the ice clearing service during four months (from 1st December to 1st April) are borne by the Prussian and Hamburg Administrations respectively.

The expenses are distributed as follows:

I. For the ice-breakers belonging to the Prussian Administration,

During the winter of 1889–90 in round numbers 26700 M.
„ „ „ „ 1890–91 „ „ „ 92300 „

The sum of 16000 M. paid to the military engineers for the partial sawing of the ice is included in this amount.

During the winter of 1891—92 in round numbers 25460 M.
„ „ „ „ 1392—93 „ „ „ 61350 „

During this last long and severe winter the ice-breakers were for the first time all at work together.

During last winter, 1893—94, when the clearing service was of short duration, the working expenses of the Prussian ice-breakers were only 25000 M.

II. For the Hamburg ice-breakers,

a. The ice-breakers I, II, III and „Elbe" which worked on the lower Elbe below Hamburg:

During the winter of	1883—84	in round numbers . . .	23500 M.
Ice-breaker I and II	1884—85	„ „ „ . . .	18900 „
	1885—86	„ „ „ . . .	25600 „
	1886—87	„ „ „ . . .	32000 „
	1887—88	„ „ „ . . .	26400 „
	1888—89	„ „ „ . . .	38600 „
	1889—90	„ „ „ . . .	37200 „
	1890—91	„ „ „ . . .	31400 „
	1891—92	„ „ „ . . .	73300 „
	1892—93	„ „ „ . . .	42100 „

During this last winter all the Hamburg ice-breakers I, II, III and „Elbe" were engaged.

b. The ice-breakers „Hofe", „Simson" and „Möve" which worked on the Northern Elbe and in the port of Hamburg:

During the winter of 1892—93 in round numbers . . 22500 M.

Last winter, 1893—94, the Hamburg ice-breakers mentioned under *a* required about 44400 M.; those under *b* about 21000 M., in round numbers 65400 M. It must also be observed that for the Hamburg ice-breakers „Simson", „Hofe" and „Möve" no particular account was kept for the time during which they were employed for clearing away ice, for they are used all the year round; but the sum indicated above corresponds to the working expenses of the boats during the space of four months (from 1st December to 1st April).

The working expenses of the Hamburg ice-breakers were last winter greater than those of the Prussian Administration. The reason of this is that the Hamburg boats went to work at the commencement of the frost, while the Prussian boats worked only during a period of ten days.

(Translated by Francis A. Oliver).

A.

TABLE SHOWING

Dimensions, Cost etc. of the ice-breaking Boats
belonging to the Prussian Administration
of Works on the Elbe.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
										Draught astern whil work	
No. of boat.	Name of Boat.	Name of Builder.	Launched.	Cost Building. Marks.	Service.	Description.	Avurage speed. Knots.	Length at water-line. M.	Beam. M.	Without ballast. M.	Ballast by the stern. M.
1.	„Wal".	Kette, Uebigau near Dresde.	1889	68000	Ice-breaking on the Elbe.	Grounding.	10,6	24,0	5,5	1,7	2,1
2.	„Delphin".	idem.	1889	42000	idem.	id.	9,6	22,0	5,0	1,52	1,82
3.	„Robbe".	idem.	1889	42000	idem.	id.	9,6	22,0	5,0	1,52	1,82
4.	„Lüneburg".	Société Anon. ship-yard (Formerly Janssen & Schmisinsky) Hamburg-Steinwärder	1890	60000	idem.	id.	9,5	18,0	4,8	1,50	1,80
5.	„Eisbär".	Möller & Holberg, Stettin.	1892	72000	idem.	id.	10,0	28,0	6,0	1,80	2,1
6.	„Walross".	idem.	1892	70500	idem.	id.	10,0	28,0	6,0	1,80	2,1
7.	„Widder".	idem.	1892	44000	idem.	Ramming.	9,0	23,0	5,0	1,60	1,8
8.	„Molch".	Kette, Uebigau near Dresde.	1892	20000	Ice-breaking in the port & accessory services.	id.	8,6	15,0	3,6	1,05	1,35
9.	„Salamander".	idem.	1892	20000	idem.	id.	8,6	15,0	3,6	1,05	1,35

14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.
	Boiler.			Engine.				Consumption of fuel per hour.	Screws.				Observations.
	Pressure.	Surface of grate.	Draught, natural or artificial.	System	Dimensions of cylinder.	Number of revolutions.	Horse-power.		Number.	Diameter.	Pitch.	Number of blades.	
M.	Kg.	sq.M.			m.M.			Kg.		M.	M.		
	10,0	2,56	Natural.	Two compound cylinders. Condensation by injection.	340 × 650 / 350	180	220	300	1	1,7	2,5	4	Steel screw.
	10,0	1,19	id.	id.	250 × 500 / 300	200	110	160	1	1,43	2,2	4	id.
	10,0	1,19	id.	id.	250 × 500 / 300	200	110	160	1	1,43	2,2	4	id.
	12,0	1,20	id.	Compound without condensation.	300 × 500 / 350	210	160	200	1	1,38	1,45	4	Bronze screw.
	10,0	2,50	exhaust valve.	Two Compound cylinders without condensation.	350 × 650 / 370	180	280	400	1	1,7	2,5	4	Steel screw.
	10,0	2,50	id.	id.	350 × 650 / 370	180	280	400	1	1,7	2,5	4	id.
714	10,0	1,275	id.	id.	275 × 510 / 350	200	160	280	1	1,43	2,2	4	id.
	10,0	0,6	id.	id.	130 × 240 / 200	350 to 400	about 60	100	2	0,85	1,1	3	id.
	10,0	0.6	id.	id.	130 × 240 / 200	350 to 400	about 60	100	2	0,85	1,1	3	id.

B.

TABLE SHOWING

Dimensions, Cost etc. of the ice-breaking Boats
of the Hamburg Administration of
Works of the Elbe.

1. No. of Boats.	2. Name of Boat.	3. Name of Builder.	4. Launched.	5. Cost of building. Marks.	6. Service.	7. Description.	8. Average speed in free water. Knots.	9. Length at waterline. M.	10. Beam. M.
1.	Ice-breaker I.	Reiherstieg ship-yard.	1874	300000	Ice-breaking on the Lower Elbe.	Grounding.	10,5	37,943	9,76
2.	Ice-breaker II.	idem.	1877	300000	idem.	id.	10,5	39,65	10,07
3.	Ice-breaker III.	idem.	1892	485000	idem.	id.	11,75	42,67	11,0
4.	„Elbe"	idem.	1892	208000	Ice-breaking on the Northern Elbe and in the port of Hamburg.	id.	9,5	28,33	7,10
5.	„Hofe"	idem.	1878	106500	idem.	id.	10,5	24,38	6,4
6.	„Simson"	Ship-yard of late Janssen & Schmilinsky.	1883	100000	idem.	id.	10,5	26,0	6,4
7.	„Möve"	idem.	1889	65000	idem.	id.	10	16,0	5,2

13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
Boiler.			Engine.					Screw.				
Pressure. Kg.	Surface of grate. sq. M.	Draught, natural or artificial.	System.	Dimensions of cylinder. mM.	Number of revolutions.	Horse-power.	Consumption of fuel per hour. Kg.	Number.	Diameter. M.	Pitch. M.	Number of blades.	*Observations.*
4	7,44	Natural	Vertical engine direct action; high and low pressure; surface condensation.	685 1370 914 Stroke of piston.	82	450	525	1	3,657	4,572	4	Steel screw.
5	7,15	id.	idem.	710 1270 914 Stroke of piston.	80	500	450	1	3,657	4,572	4	Bronze screw.
12	9,2	id.	Vertical engine direct action; high low and medium pressure; surface condensation.	560 890 1480 1066 Stroke of piston.	80	1050 to 1200	880	1	3,962	5,180	4	idem.
6,3	3,2	id.	2 vertical engines direct action; high and low pressure; surface condensation.	350 700 500 Stroke of piston.	130	320	350	2	1,900	2,743	4	idem.
6	2,2	Artificial	idem with condensation.	460 711 Bore 534 Stroke of piston.	162	280	290	1	1,830	2,2	4	Bronze screw of 920 Kg.
6½	3,8	Natural	idem.	430 710 Bore 550 Stroke of piston.	168	350	360	1	1,980	2,15	4	Bronze screw of 960 Kg.
12	1,4	Artificial	idem with exhaust valve.	250 420 Bore 320 Stroke of piston.	215	330	445	2	1,40	1,625	4	Bronze screw of 425 Kg.

a.	Longueur.	Länge.	Length.
b.	Largeur.	Breite.	Width.
c.	Hauteur sous pont.	Höhe unter Deck.	Height under deck.
d.	Tirant d'eau.	Tiefgang.	Draught.

Lüneburg
a = 18.80 m.
b = 14.77 „
c = 2.20 „
d = 1.50 „

Elbe
a = 42.67 m.
b = 10.67 „
c = 5.49 „
d = 4.36 „

Molch & Salamander
a = 14.04 m.
b = 3.68 „
c = 1.28 „
d = 1.— „

Wal
a = 24.75 m.
b = 5.50 „
c = 2.55 „
d = 2.— „

Eisbär & Walross
a = 28.50 m.
b = 6.— „
c = 2.80 „
d = 1.80 „

Widder
a = 23.55 m.
b = 5.— „
c = 2.34 „
d = 1.60 „

Delphin & Robbe
a = 22.55 m.
b = 4.80 „
c = 2.30 „
d = 1.45 „

Hofe
a = 24.38 m.
b = 6.40 „
c = 3.— „
d = 2.20 „

NARTEN.

8

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS
THE HAGUE 1894.

3nd QUESTION.

MEANS FOR PREVENTING ICI BLOCKADES

BY

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MEANS FOR PREVENTING ICE BLOCKADES

(Methods adopted on the Seine).

REPORT

BY

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Navigation on the Seine is made possible by the employment of moveable dams and as these are opened in time of frost it follows that navigation is necessarily suspended.

In these circumstances the only means taken for the removal of the ice from this river during hard frosts have for their object the protection of the navigation plant and the craft lying in the river and the destruction of dangerous ice-fields.

This work, generally managed by the employés of the navigation service, assisted when necessary by additional workmen, for the breaking and clearing away of the ice, only allows of the use of wherries, axes, boat hooks etc., extremely simple means, which have always been found sufficiently effective.

During the severe winter of 1890—91, the interruption of navigation being exceptionally prolonged (1), the shipping services on the Seine between Paris and Rouen were induced at the urgent request of the navy to attempt some operations on a large scale for the removal of the ice, in order to hasten the recommencement of navigation as soon after the thaw as possible and at the same time to ensure the destruction of the masses of ice which threatened the constructive works — sluices, dams and bridges — and the protection of the craft and numerous floating plant in the immediate neighbourhood of Paris.

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(1) From December 14th 1890 to January 26th 1891, or 43 days.

We propose to give some account of these operations, dwelling only in order to avoid unnecessary repititions upon those which presented certain peculiarities in the methods pursued.

In order to be able to make clear under what conditions of temperature these operations were effected, we have indicated on Plate I the daily curves of minimum temperature observed during the period included between December 4th 1890 and January 26th 1891 (at two points on the lower Seine, viz. at the locks of Bougival, kilometre 48.50, and at the locks of St. Aubin, kilometre 217.00).

BRIDGE OF ASNIÈRES AND THE BRANCH STREAM OF PUTEAUX.

On January 16th 1891 the navigable branch of the Seine, which keeps near the left bank and is known as the Puteaux branch, was frozen between kilometre 17.60 (600 m. below the dam of Suresnes) and kilometre 21.30, that is over a distance 3.70 kilometres, the part situated below the bridge of Courbevoie being especially blocked by an ice-bank; as for the little branch on the right bank, called the Heuilly branch, it was entirely frozen from below the dam of Suresnes to the Ile de la Grande Jatte, or over a distance of 4.90 kilometres (Plate II).

The ice on the small branch was at this point connected with the ice-bank that covered the whole river between kilometre 22 and the bridge of the Ouest railway at Asnières, over a length of about 600 m. and a width of 110 m. This bank was composed of ice formed at this point and by numerous pieces brought down from up stream at the commencement of a thaw; its thickness, very inconsiderable near the shore, especially at the right bank, increased over two thirds of the width, where it reached 2 m. or 2.50 m., to decrease again towards the left bank near which it became very irregular.

As regards its formation this ice-bank was composed of a layer of strong ice 0.15 or 0.25 m. thick, from under which pieces of ice emerged, generally on the up stream side, at an angle of 30°, forming projections of 0.60 or 0.70 m., and below this layer the thickness was increased by a mass of fragments more or less welded together and mingled with a quantity of rotton ice.

In order to get rid of this ice-bank which by stopping the flow of ice from up stream might at any moment become dangerous for the railway-bridge, recourse was had to the simultaneous employment of ice-breaking boats worked by gangs of workmen and blasting superintended by a detachment of military Engineers.

The ice being thinner on the right the first operation was to dig a channel along this bank by means of a simple Norman wherry suitably plated with iron (Plate III) hauled along by four horses, twelve men giving it a heavy rolling movement.

This channel being once open the ice-bank proper was next attacked and after a few preliminary attempts to ascertain the most advantageous manner of employing the explosives, the plan that we are about to describe was determined on.

In a line parallel to the open channel holes 0.40 deep were dug in the ice by means of pickaxes at a distance of 3 or 3.50 m. apart. In these were placed charges composed of two *pétards* or cartridges of melinite.

The charges were connected by means of fuses which were united by one single fuse ending in a Bickford match.

From this main line of fuses transverse lines at every 30 or 40 m. connected a series of charges arranged like the first.

All these charges and fuses were covered with broken ice by way of tamping and where the ice was uneven the surface was cut away.

When the Bickford match was fired all the charges went off at the same time and thanks to their action and that of the fuse slices 300 m. long by 15 or 18 m. wide were detached from the ice-bank and were sufficiently dislodged by the transverse charges for them to be able to pass through the arches of the bridge; this movement was superintended and assisted when necessary by a small steamer, the *Jeanne*, of 80 horse-power, protected in the bows by metal plating (Plate V).

Nearer the left bank where the ice was not so thick it was sufficient to dislodge it to employ charges of one *pétard* only placed at intervals of 3 m. from one another in cavities 6 or 7 centimetres deep.

The destruction of this ice-bank being completed on the 20th January, the opening of the channel in the Puteaux branch was commenced the next day.

The ice upon this branch extended over 3.70 kilometres and was 0.20 or 0.30 m. thick without counting the loose pieces accumulated below and separated by a quantity of slush; as for the portions of the blocks which rose above the surface, in consequence of their exposure to the air, they had become porous and easily crumbled away.

Along the left bank the ice was thin and in some places there was open water in consequence of the presence of numerous drains some of which conveyed warm water from factories.

The ice-bank which blocked the lower part of the branch was composed of flakes of ice which had settled at an angle of 45° down stream, while up stream having met with no pressure they remained horizontal.

The means employed for the removal of the ice from this branch, without entering into details, were as follows:

I. A channel towards the middle of the branch was opened by means of charges connected by a main line of fuses 25 or 30 m. long, arranged as for the ice-bank at the bridge of Asnières, without having recourse to transverse lines except when the width of the river required it or to *pétards* placed on the surface except where the ice was thin.

2. A steamer suitably protected was made to pass up and down in the channel prepared by the melanite and by means of this boat and a wherry the complete breaking up of the detached blocks was effected.

By proceeding in this way the ice was removed from the branch stream over a distance of 2500 m. during the 21st and 22nd January and on the 23rd, in consequence of the thaw, the steamer and the wherry sufficed to completely clear the Puteaux branch, a few *pétards* however being placed on the surface of the larger pieces.

Briefly, the clearing of the navigable branch of the Seine between the bridge of Asnières and the dam of Suresnes, over a distance of 4.30 kilometres, required about one week's work and cost, including the explosives and the allowances made to the men forming the detachment (1) of Engineers, in round numbers fr. 15000, equivalent to an expenditure of fr. 3.40 per metre in distance down the river. The destruction of the ice-bank at the bridge of Asnières was included in this sum.

The explosive materials consumed were:

Cartridges	1047
Pétards	813
Fuses	3960 m.
» instantaneous	380 »
Blasting caps	1182

MARLY BRANCH.

The Marly branch with an average width of 70 m. and total length of 11 km. is closed 8 km. below its mouth by the waste-weir of Marly.

The ledge of this construction being so high that the water cannot pass over it in time of drought, when the dam of Bezons which helps it to close the dam of Bougival is open, the ice had completely invaded this branch and being deprived of all current both above and below the dam of Marly had there formed a covering for the most part perfect and transparent of an average thickness of 0.25 m., constituting an ice-field in the navigable branch.

Under these circumstances it was to be feared that this ice when the flood accompanying the thaw should come would produce either an ice-bank that would endanger the safety of the dams, sluices and boats docked in large numbers above the latter, or an accumulation of ice immediately below the Marly dam, which might provoke a considerable rise in the water followed by an almost instantaneous fall the moment this obstacle should be broken. Either of these contingencies was calculated to have disastrous consequences both for constructive works and for boats.

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(1) This detachment commanded by a lieutenant consisted of 1 non-commissioned officer, 1 corporal and 17 sappers.

To prevent any occurence of this serious nature the following steps to clear away the ice were taken.

On January 26st 1891 the opening of a channel 4 m. wide was begun at the end below the Marly bank by means of blasting managed by a detachment of engineers and axes and wherries worked by a gang of civilians. This channel 2 km. long, between kilometres 49.30 and 51.30, was finished on January 23rd after eight days' labour.

On January 24th the military detachment passed over to the Seine above Bougival and continued the central channel which on the 25th reached as far as La Grenouillière (kilometre 46.50).

Between January 21st and 25th inclusive a gang of workmen by means of saws and axes and without the aid of explosives, for fear of shaking the neighbouring works, opened a central channel beginning at the Marly dam 400 m. long with a width of 4 m. and 200 m. with a minimum width of 8 m. Finally a branch was made of the same width which terminated at the large lock of Bougival in order to open a passage to the latter for the boats lying up stream (see Plate VI).

On January 26th and 27th, immediately before the general breaking up of the ice, the whole bank of ice which covered the basin above the locks of Bougival over an area of about 5000 sq.m. was dislodged by a gang of workmen on a wherry, a strong steam-boat and a few *pétards* laid on the surface.

The following was the method adopted for removing the ice by blasting.

a. On wooden rods 4 m. long a row of melinite cartridges was placed 0.80 to 1.00 m. apart, which were composed of 100 to 135 grammes a piece and connected by a train, also of melinite. The rods made ready on shore were simply placed upon the ice where they were joined end to end so as to form lines 50 m. long.

The tamping was first effected by covering them with a cap of earth about 0.20 m. thick, but this earth not being suitable to produce the desired effect the rods were placed at the bottom of a groove in the ice formed with pickaxes which was filled up with snow and broken ice.

By means of this arrangement which was fired by a Bickford match a channel 3.00 or 3.50 m. wide was opened in a coating of strong ice 0.20 to 0.30 m. thick. (Plate VII, fig. 1.)

The fragments produced by the blasting were long in form and numerous cracks were made in the ice along the bank.

The pieces of ice in the channel were next broken up and got rid of by means of a wherry and by men with hooks and axes, but this operation was very slow on account of the absence of current.

This method at once simple and rapid as far as the blasting was concerned had however the inconvenience of producing very violent vibrations in the atmosphere at the moment of the explosions, breaking the windows in houses near the river and even at a distance of 200 m., and in fact entailed heavy expense considering the cost of the melinite cartridges (fr. 12 the kilo.) and fuses (fr. 0.40 the metre). It was consequently abandoned after the fourth day and replaced by the following:

b. In the middle of the channel to be opened holes were bored every five metres through which charges composed of five cartridges or four melinite *pétards* were let down below the ice and were fired by the Bickford match.

The explosion of these charges formed holes 3.50 to 4.00 m. in diameter (Plate VII. fig. 2), which remained separated by strips of dislodged ice which the workmen demolished with axes at the same time as they regulated the passage and freed it from broken fragments.

This latter operation requiring much time the following was substituted for it:

c. At a distance of 5 m. apart and towards the middle of the branch stream two grooves were made in the ice 0.10 m. deep; then in the centre of this strip holes 0.20 in diameter and 5 m. apart were dug with pickaxes through to the water (Plate VII, fig. 3). In these holes 0.30 or 0.40 m. below the ice charges of melinite of 0.5 kilo. were placed. They were composed of five cartridges or four *pétards* fixed on a wooden rod to which was attached a Bickford match with a blasting cap.

For the sake of economy in some places charges of Favier safety powder were substituted for melinite, as it is much less expensive (fr. 3.25 the kilo.), even including the increased weight of the charges necessary to obtain the same result (about $^{1}/_{4}$ or $^{1}/_{5}$).

Considering the less violent action of this explosive the charges were let down a little lower than those of melinite.

Each explosion completely dislodged the ice between the grooves, that is over a width of 5 m., and it was sufficient in order to clear the channel to remove the fragments and rotten ice with boat-hooks.

In the places where the coating of ice was formed of pieces welded together, as in the branch stream of Bougival above the village, the grooves could without difficulty be dispensed with.

By this method a channel 800 or 900 m. long was opened up every day by a gang of 20 soldiers and 30 to 35 workmen.

The quantity of explosives used in the different operations on the Bras de Marly by the detachment of Engineers was as follows:

Melinite (*pétards* or cartridges) . . .	200 kilo.
Favier powder	160 "
Explosions produced were about . . .	850

Per metre in distance of the channel opened the cost of explosives amounted to fr. 0.75 when melinite was used and only fr. 0.40 when Favier powder was substituted for it.

As regards the channel formed without blasting above the dam of

Marly and in the neighbourhood of the locks of Bougival, the following is the manner in which it was opened.

By means of stone-saws (Plate VII, fig. 4), as shown in the annexed sketch, worked by two men relieved every half hour the ice was sawn through in parallel lines 4 m. apart.

In the strips thus detached by means of hatchets (Plate VII, fig. 5) transverse trenches 0.10 m. wide by 1.20 to 1.30 m. long were cut 4 m. apart by means of saws (Plate VII, fig. 6).

The blocks of ice once freed were pushed with boat-hooks under the ice that remained intact at each side of the trench.

It should however be added that this method was only effective because the ice was hard and strong and about 0.25 m. thick.

The trench in question, which including its branch was 760 m. long, was made in a day and a half by 20 workmen and cost fr. 405 in labour, equivalent to fr. 0.60 per metre in length and fr. 0.65 including the purchase or hire of materials.

As regards the cost this system of clearing away the ice is much more economical than blasting when circumstances admit of it.

Briefly, the work done on the Bras de Marly which had for result the opening of a channel over a distance of 4.3 km. lasted 12 days and cost fr. 6646.74 including the allowances made to the men of the detachment of Engineers.

The average cost per metre in length of the channel therefore amounted to fr. 1.54.

LOCK-DAM OF MÉRICOURT SANDRANCOURT.

Between the 19th and 20th January a field of ice had formed about 1500 m. above the dam of Sandrancourt (kilometre 117) over a distance of more than 2 km. (Plate VIII). It was composed of pieces of ice 0.20 m. thick, raised up vertically in some places, in others lying one on the other to a height of 2 or 3 m. and closely welded together. Moreover the river was completely frozen over for a distance of about 10 km. above the dam.

On account of the bend in the river this ice-field directly threatened the locks of Méricourt on the left bank as well as the timber works adjoining them and the sluices of the channels above the dam.

The object of the measures taken to ward off these dangers was to determine a line through the broken ice of less resistance towards the right bank in order to draw the flow of the ice on this side when the thaw came. The operations were commenced on the 22nd January and were terminated on the 25th. They consisted in breaking with hatchets and with the help of men in boats the ice in the immediate neighbourhood of the dam and in opening over a distance of more than one kilometre above the deep channels and across the ice-bank a channel 20 to

30 m. wide. To accomplish this explosives were let down through the ice and as has been said above boats went to work where ruptures were produced by the blasting.

This work was accomplished with the help of a detachment of Engineers and a gang of 12 workmen.

The quantity of explosives employed was about 50 kilo. of Favier powder and 10 kilo. of melinite.

The cost including the allowances made to the men of the detachment (1) of Engineers amounted to fr. 150000.

The result aimed at was perfectly realised and upon the breaking up of the ice the fragments flowed on to the right bank.

Considering only the length of the channel opened the expense was fr. 1.50 per metre, but as a matter of fact the area of the ice destroyed was not less than 40000 sq.m. and that of the coating which covered the river over a distance of 10 km. above the dam and which flowed through the channel when the ice broke up exceeded 200000 sq.m.

LOCKED BRANCH OF AMFREVILLE-SOUS-LES-MONTS.

As the locked branch of Amfreville-sous-les-monts (Plate IX) presents a length of 1900 m. and a width of 50 m., except close to the sluices where it is as much as 80 m., and the ice which forms on it can only be cleared away through the locks, it was of the highest importance not to let the pieces freeze together, for to remove the ice after the thaw might cause a delay of 10 to 15 days in the reopening of navigation.

From 14th December to 16th January the ice was broken as fast as it formed, boats manned with men armed with boat-hooks and axes and an ice-breaking boat made out of a large Norman wherry armed with strong plates of iron (Plate X) being made to sail up and down. This boat with men on board was towed by horses and according to the circumstances went to work as follows:

The men being placed astern the boat was hauled so as to slide her bows on to the surface of the ice. All the men then went forward and by keeping time in a series of jumps caused the ice supporting the boat to give way and cracked that which remained still fast.

Now if these cracks were sufficiently pronounced the boat was set going in the direction of one of them and the men on board giving her a heavy rolling movement an energetic motion was set up in the water which caused numerous cracks in the ice in every direction and at considerable distances.

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(1) This detachment commanded by 1 lieutenant was composed of 1 non-commissioned officer and 5 sappers.

All the fragments thus produced, after being sufficiently broken, were then passed through the locks.

These means becoming insufficient recourse was had on the 17th January to blasting effected by a detachment (1) of Engineers.

By this time the ice covered the whole of the branch of Ampreville and presented a thickness varying from 0.35 to 0.50 m. The upper surface was fairly united, but below were some loose fragments which in some places formed a total thickness of 1.50 m.

The following were the arrangements employed for breaking the ice (Plate XI).

On wooden rods 5 m. long were placed at equal distances apart charges composed, at the ends, of 1 cartridge of melinite and two cartridges of dynamite; the other charges were formed of one cartridge of dynamite, except the fifth from the cap which was composed of a cartridge of melinite.

All these charges were connected by a fuse one metre longer than the rods that it might be attached to a line of the same substance.

Each arrangement was composed of 6 rods, the 4 in the middle being in a straight line and the first and the last being inclined to it like the sides of a trapeze.

These rods were placed charge downwards in trenches 7 or 8 centimetres wide and the whole was covered with fine sand by way of tamping.

The explosion of these charges caused the separation of slices of ice as much as 40 m. in length and 12 to 15 m. wide, but in general on account of the sluices it was sought to obtain smaller pieces.

The connecting fuse having failed the work was continued in isolated charges composed of 2 or 3 *pétards* or cartridges let through to the water in holes bored in the ice 3 m. apart; these charges were primed with a Bickford fuse.

The clearing away of the ice from the branch stream at Ampreville-sous-les-monts was completed on 21st January by the detachment of Engineers with the help of a gang of 4 workmen.

The quantity of explosives used was:

Melinite	22 Kg.
Dynamite	40 »
Fuse	300 M.
Bickford fuse	70 »
Blasting caps	700

The cost including the allowances made to the detachment of Engineers amounted to fr. 772.00, representing an expenditure of fr. 0.40 per metre in length of a channel 1900 m. long with an average width of 30 m.

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(1) This detachment commanded by a lieutenant was composed of 1 non-commissioned officer and 5 sappers.

THE REACH OF ROUEN.

On the 22nd December 1890 the movement of boats on the Rouen reach, the depth of which is not secured by any dam, but is susceptible to the changes in the tide, was no longer sufficient to keep the channel free. At this time the whole Seine was frozen from Elbeuf to Rouen, ice-banks had formed at the bridge of Brouilly in front of Mivoie and St. Etienne du Rouvray, and lastly at Oissel a field of ice stretched between kilometres 226 and 232 and held fast the bridge of the railroad from Paris to Rouen (Plate XII).

Three steamboats the *Isard* (300 horse power), the *Assistant* (60 h. p.) and the *Hirondelle* (50 h. p.) were then set to work to break the ice. They were armed to protect their bows with shields placed at the level of the water line. That of the *Hirondelle* in particular (Plate XIII) was formed of a layer of wood 0.80 m. thick in the form of a V embracing the stem and covered with sheet steel 10 mm. thick, 0.50 m. high and 2 m. long, lengthened on each side by a sheet of iron 0.07 by 1.50 m.

These boats broke the ice either by penetrating by main force or by the agitation they produced in the water without occasioning any damage to the banks by their movements straight ahead followed by abrupt movements astern, which by causing an upheaval in the water followed by a rapid depression had a very powerfully destructive action on the ice.

Moreover these operations could only be performed during the ebb-tide, for during the flood the broken ice could not flow away.

The length of various ice-banks destroyed in this way every day over the full navigable extent of the branch varied from 250 to 500 m. according to the thickness of the ice, which in some places was 0.55 m.

The boats in question were also employed every day between Oissel and Rouen for breaking the ice which kept on forming in the trench, the thickness of which was about 0.02 m., as well as the banks of ice which were formed by the effect of the tide.

Thanks to these manœuvres and the use when the general breaking up of the ice took place of some *pétards* of Favier powder (3660 kg. in all) placed on the surface of the larger blocks to split them up, the ice was carried away with the greatest ease on 24th January 1891 without any damage being done either to the bridge of Oissel or the bridge of Brouilly.

The cost of clearing away the ice from the reach of Rouen amounted to fr. 2866.60 including the expenses incurred by the steam-boats, which however were only employed 23 days between 22nd December 1890 and 24th January 1891.

Considering only the portion of the river included between the ice-field above Oissel and the port of Brouilly (13 km.) the cost of clearing away the ice per metre in length amounted only to fr. 0.22, but it should be added that if this expenditure was sufficient to ensure a rapid disappearance of the ice without accident, it failed to maintain a channel constantly free between Rouen and Oissel. This however it was not sought to do the navigation being at this time interrupted between Paris and Rouen on account of the locks being open for the passage of the ice; moreover the steamers employed were not strongly enough built for such operations and frequently were damaged.

PORT OF ROUEN.

During the winter of 1890—91 the sea-port of Rouen was in no part blocked with ice, but this was not the case with the river-port where the ice from up stream was inclined in different places to form fields of ice, especially above the bridge of Boïeldieu and the bridge of Brouilly; also the timber and petroleum docks were frozen over and the ice was fairly thick (Plate XII).

The ice-fields in the river-port being of a nature calculated not only to interfere with the river navigation, but also to endanger the safety of the boats and bridges when the ice should break up on the Seine, armoured steamboats were employed to clear it away as fast as it should form.

As regards the ice in the timber dock, which it was desirable to employ for the river boats, and in the petroleum dock, the entrance and outlet to which had to be kept free, it was found possible to ged rid of it by cutting it into large and regular blocks by means of pickaxes; these were towed into the channel and care was taken to break them with the tug before abandoning them to the current (1).

During the winter of 1890—91, no ice-field was produced on the Seine below Rouen, except opposite Caumont in a contracted part of the river.

This field of ice due probably to the too energetic clearing away of the ice in the port of Rouen and the reach above the town, an operation which on this account had to be momentarily suspended, did not prevent the navigation of sea-going vessels. However, as this might have resulted had the frost continued, it was attacked down stream by steamboats during the ebb, so as to ensure the broken ice being carried down by the current.

The expense incurred by the port of Rouen in the clearing away of the ice amounted in round numbers to fr. 4000.

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(1) The service of the port of Rouen possesses at present one strong tug, the *Edouard Lavoinne* (300 h. p.), which can be provided with a mask protecting the bows and which breaks the ice without the previous use of pickaxes.

CONCLUSION.

It results from the different examples we have cited of the operations for clearing away the ice from the Seine during the severe winter of 1890 – 91, *that a channel may be opened in ice* 0.50 *thick and in ice-fields or banks* 3.00 *m. thick by having recourse to ice-breaking boats, blasting or sawing, or by the simultaneous use of these different methods; but the clearing of the channel cannot be satisfactorily effected unless the operations are conducted when the temperature is rising and the thaw is at hand.*

The cost of operations of this nature cannot be fixed, as it varies greatly according to the local circumstances, but it seems as far as may be gathered from the few experiments quoted that the methods based on the employment of mechanical means such as ice-breaking boats and especially the saw give results more economical than and as rapid as those obtained by blasting.

The latter method however is particularly serviceable when it is required to rapidly dislodge thick masses of broken pieces more or less welded together forming ice-banks or fields which threaten the safety of constructive works, but it is necessary at the same time to employ boats and gangs of workmen to ensure the breaking up and removal of the fragments produced by the blasting.

Translated by FRANCIS A. OLIVER.

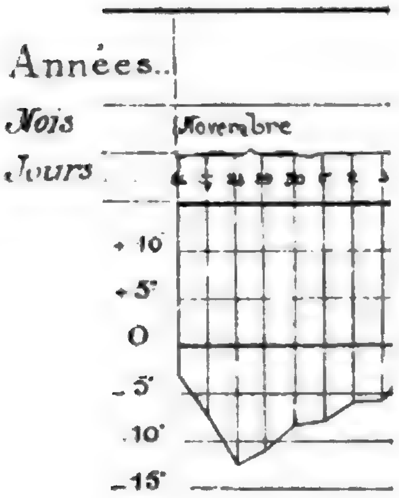
Inscriptions des Planches.	Inschriften der Zeichnungen.	Description of the Plates.
PLANCHE I.	BLATT I.	PLATE. I.
Températures minima observées chaque jour pendant la période de glaces de 1890—1891.	Während der Eisperiode 1890/91 täglich beobachtete Minimaltemperaturen.	Minimum temperatures observed every day during the period of ice, 1890—1891.
Années. — Mois. — Jours.	Jahr. — Monat. — Tag.	Years. — Months. — Days.
PLANCHES II, VI, VIII, IX, XII.	BLATT II, VI, VIII, IX, XII.	PLATES II, VI, VIII, IX, XII.
Rivière libre.	Offenes Wasser.	Open water.
„ prise.	Zugefrorene Strecken.	River covered with floating ice.
„ embaclée.	Eisstand.	River covered with masses of ice.
PLANCHE III.	PLATT III.	PLATE III.
Bachot normand employé comme brise-glace en amont des ponts d'Asnières.	Normännischer Kahn, welcher oberhalb der Brücken von Asnières als Eisbrecher benutzt wurde.	Norman wherries employed as ice-breakers above the bridges of Asnières.
Plan.	Flächenriss.	Projection.
Elévation.	Längsschnitt.	View.
Tôle.	Eisenplatte.	Sheet iron.
Détails du plat-bord.	Darstellung des Dahlbords.	Details of the gunwale.
Coupe suivant a . . . b.	Querschnitt in der Linie a . . . b.	Section following a . . . b.
Bordage et fond.	Bordwände und Boden.	Planking and bottom.
Chêne.	Eichenholz.	Oak.
Râbles de 0,8 au milieu.	Bodenstücke von 0,8 in der Mitte.	Bottom bars 0.8 in the middle.
Sommiers.	Mittelbalken.	Cross bars.
Epaisseur.	Dicke.	Thickness.
PLANCHE IV.	BLATT IV.	PLATE IV.
Déglaçage de la Seine, en amont des ponts d'Asnières.	Enteisung der Seine oberhalb der Brücken von Asnières.	Clearing of ice from the Seine above the bridges of Asnières.
Croquis indiquant la disposition des explosifs.	Die Vertheilung der Sprengladungen.	Sketch indicating the arrangement of explosives.
Embâcle.	Eisstand.	Ice-floe.
Couche peu épaisse.	Dünnes Eis.	Thin covering.
Banquise.	Eisbank.	Bank of ice.
Partie déblayée à l'aide de bateaux.	Mittels Schiffen enteister Theil.	Portion cleared by means of boats.
PLANCHE XI.	BLATT XI.	PLATE XI.
Déglaçage de la dérivation d'Amfreville.	Enteisung des Seitenarmes von Amfreville.	Clearing of ice from the branch-stream of Amfreville.

CAMÉRÉ.

Détail de la répartition des charges sur chaque tringle.	Anbringung der Sprengladungen auf Leisten.	Particulars respecting of the distribution of charges on each rod.
Cordeau détonant.	Zündschnur.	Fuse.
Dispositif comprenant six tringles.	Zusammenstellung von sechs Leisten.	Plan consisting of six rods.
PLANCHE V.	BLATT V.	PLATE V.
Bateau à vapeur „Jeanne" à deux hélices.	Der zweischraubige Dampfer „Jeanne".	Steamboat „Jeanne", two screws.
Plan d'ensemble.	Flächenriss.	General horizontal projection.
Coupe horizontale.	Wagerechter Schnitt.	Horizontal section.
Cornière.	Winkeleisen.	Angle-iron.
Blindage en madriers de chêne.	Deckwerk aus Eichenbohlen.	Covering of oak joists.
Elévation longitudinale.	Längsschnitt.	Longitudinal elevation.
Dessus du pont, le bastingage enlevé.	Deck nach Abnahme der Schanzkleidung.	Above the deck, netting removed.
Elévation vue d'avant.	Vorderansicht.	Elevation, front view.
Dessus du bastingage.	Obertheil der Schanzkleidung.	Above the netting.
Elévation latérale.	Seitenansicht.	Elevation, side view.
Nez du vapeur.	Nase des Schiffes.	Bow of the steamer.
PLANCHE VII.	BLATT VII.	PLATE VII.
Fig. 1. Chenal ouvert au moyen de chapelets de cartouches réunis par un cordeau détonant.	**Fig.** 1. Rinne, geöffnet vermittelst Patronenkränzen, welche durch Zündschnüre unter einander verbunden.	**Fig.** 1. Channel opened by means of a row of cartridges united by a fuse.
Fig. 2. Entonnoirs produits par des charges descendues dans des forages creusés dans la glace.	**Fig.** 2. Trichter, erzielt durch Ladungen, welche durch in das Eis gemachte Bohrlöcher versenkt wurden.	**Fig.** 2. Holes produced by charges placed below the ice.
Fig. 3. Dispositif d'explosifs avec forages et rainures latérales.	**Fig.** 3. Seitliche Einschnitte und Bohrlöcher mit Sprengladungen.	**Fig.** 3. Plan of explosives with borings and side-grooves.
Rainure pratiquée à la hache.	Mit der Axt gemachter Einschnitt.	Groove formed with axe.
Fig. 4. Scie à pierre tendre.	**Fig.** 4. Säge für weichen Stein.	**Fig.** 4. Soft stone saw.
Dents.	Zähne (der Säge).	Teeth.
Fig. 5. Hache.	**Fig.** 5. Axt.	**Fig.** 5. Axe.
Fig. 6. Dispositions des opérations d'une tranchée à la scie.	**Fig.** 6. Anordnung der Arbeiten zur Öffnung einer Rinne vermittelst der Säge.	**Fig.** 6. Arrangement for opening a channel by means of saws.
PLANCHE X.	BLATT X.	PLATE X.
Bachot normand employé comme brice-glaces dans la dérivation d'Amfreville.	Auf dem Seitenarme von Amfreville als Eisbrecher benutzter normännischer Kahn.	Norman wherry employed as ice-breaker in the branch river of Ampreville.
Plan supérieur (le plancher enlevé).	Obere Ansicht (nach Wegnahme der Dielung).	Upper section (floor removed).
Blindage en tôle.	Verkleidung mit Eisenplatten.	Covering with sheet-iron.
Coupe.	Schnitt.	Section.

PLANCHE XIII.	BLATT XIII.	PLATE XIII.
Remorqueur „Hirondelle".	Der Schleppdampfer „Hirondelle".	Tug „Hirondelle".
Installation du brise-glace.	Anbringung des Eisbrechers.	Fitting up of the ice-breaker.
Elévation du remorqueur.	Längschnitt des Schleppdampfers.	Plan of the Tug.
Coupe en maître-bau.	Durchschnitt im Hauptspant.	Section amidships.
(Pour les autres inscriptions, voir les traductions „Planche V").	(Die übrigen Ausdrücke siehe Uebersetzung zu Blatt V).	(For other descriptions, see translation of Plate V.)

Inscriptions souvent répetées.	*Oft wiederholte Inschriften.*	*Words frequently repeated.*
Barrage.	Wehr.	Dam.
Echelle.	Maasstab.	Scale.
Ecluse.	Schleuse.	Sluice (also lock).
Cornière.	Winkeleisen.	Angle-iron.
Coupe.	Schnitt (Längs-, Querschnitt).	Section.
Tôle.	Eisenplatten (Eisenblech).	Sheet-iron.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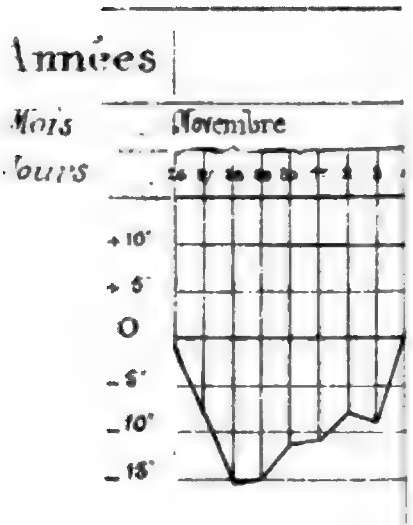
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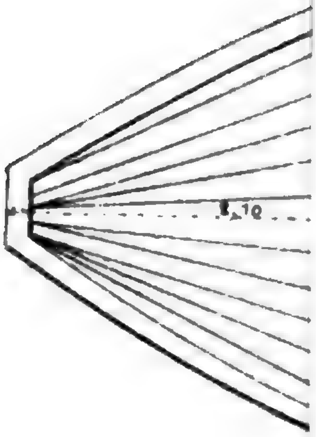

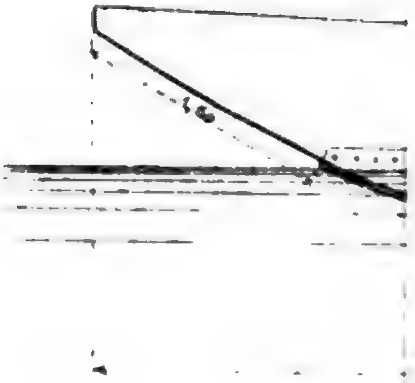

Détails

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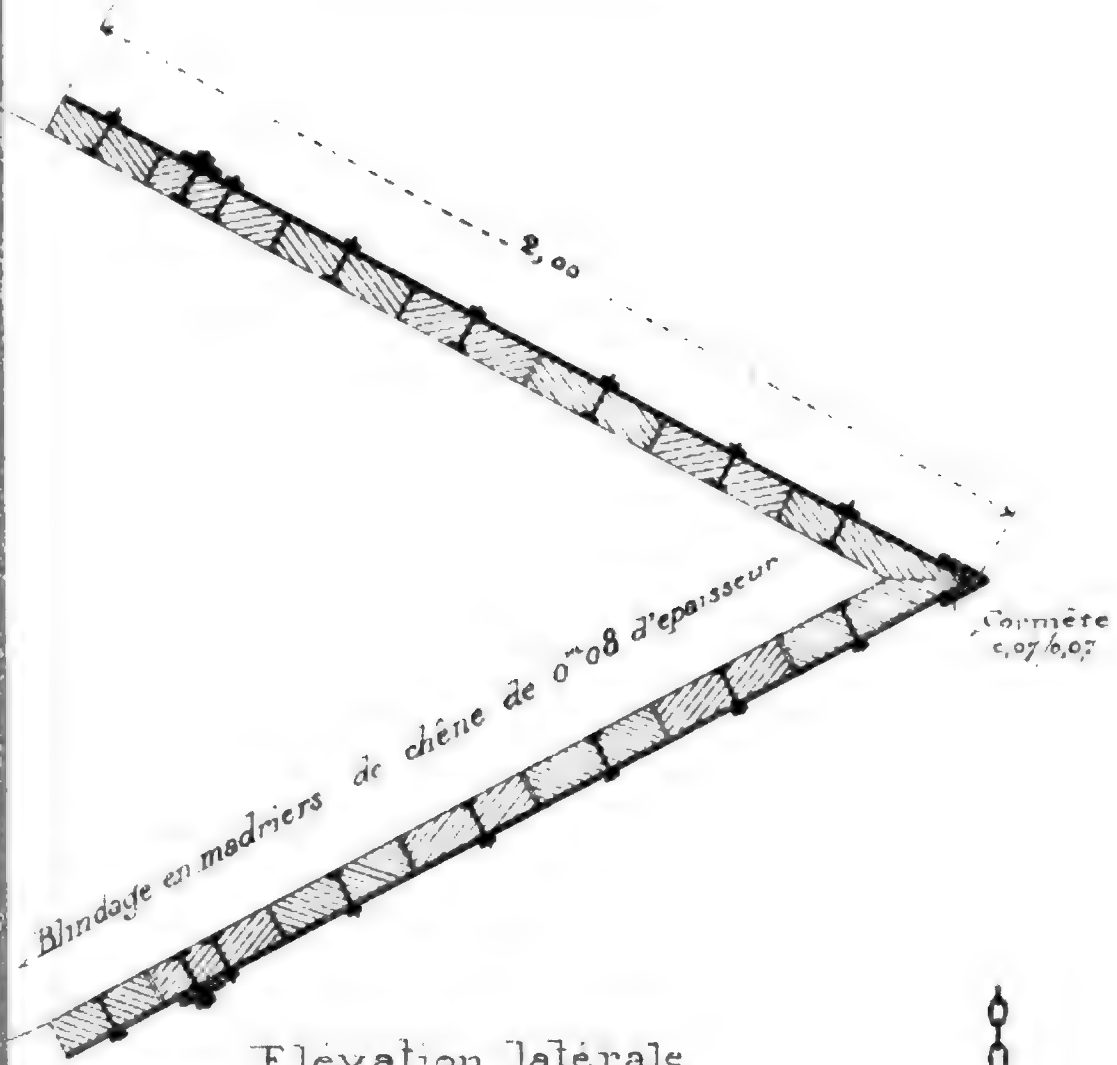
Planche N°. V.

DETAILS DU BRISE GLACE.

(Echelle de $\frac{1}{20}$)

Coupe horizontale



Elévation latérale

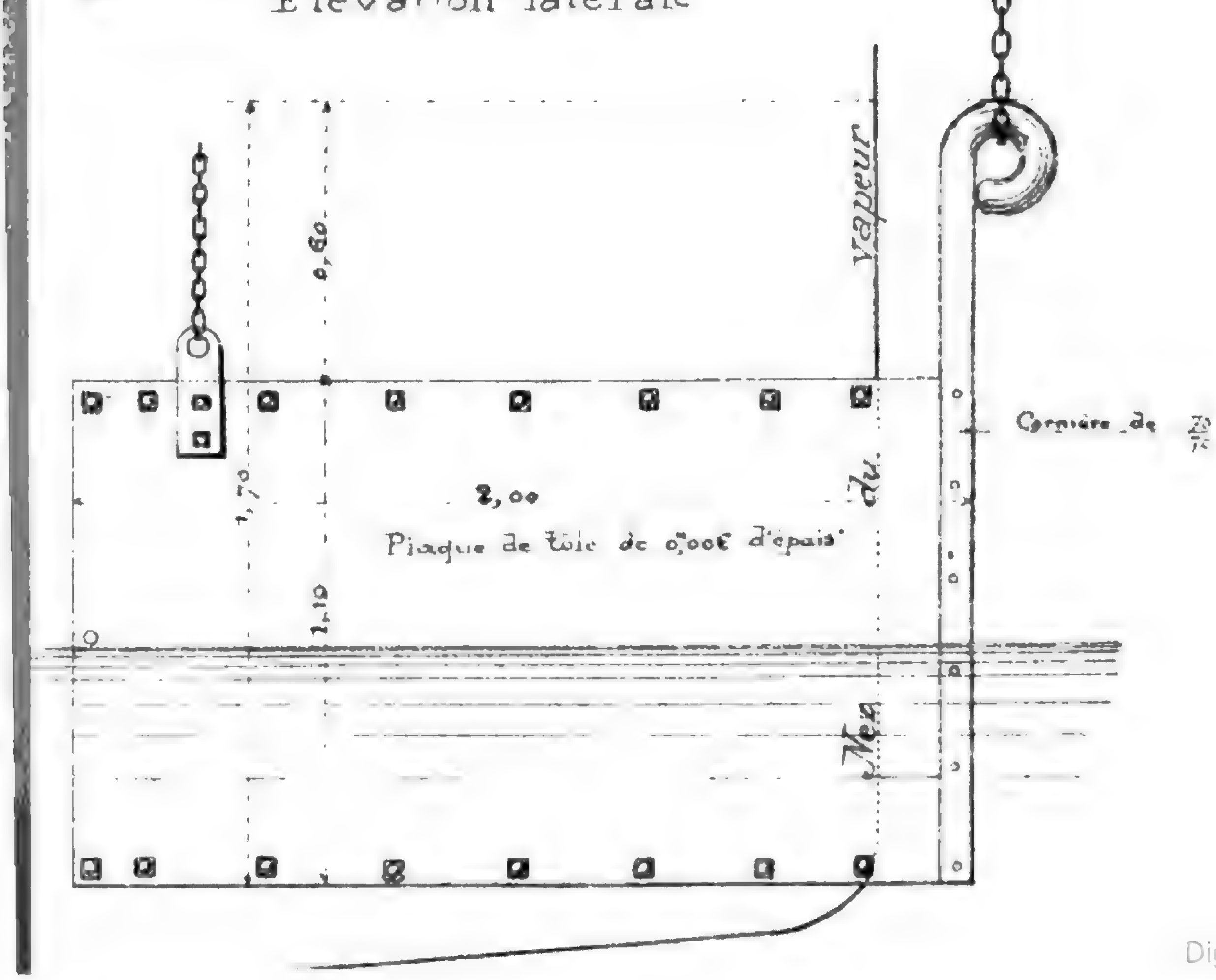


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Planche N°. VII.

fig 4

Scie à pierre tendre

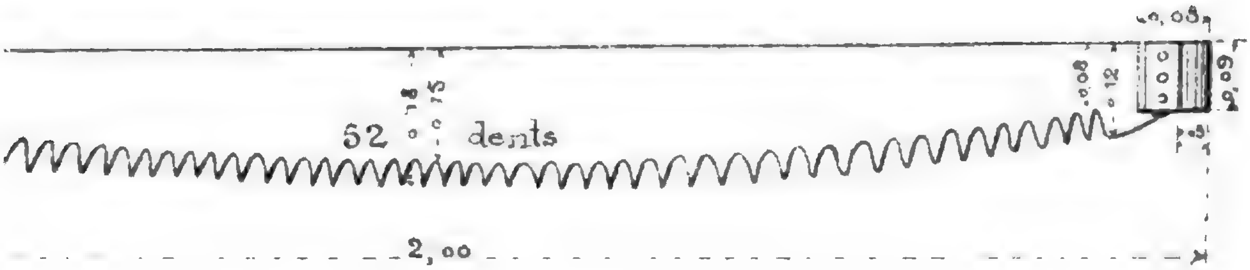


fig 5

Hache

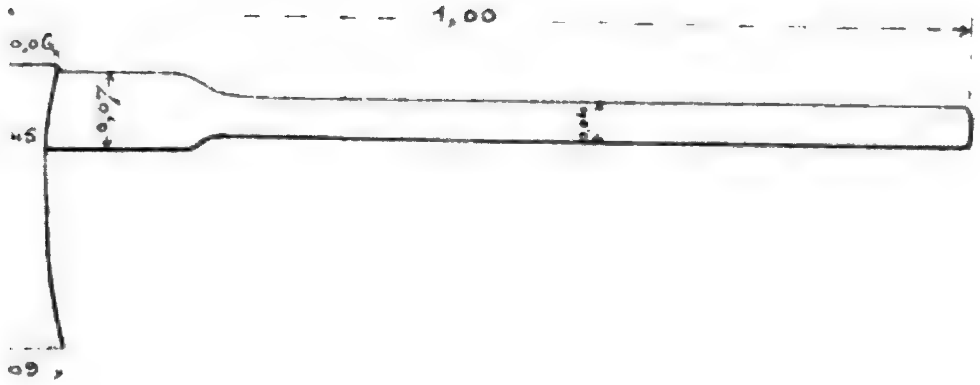
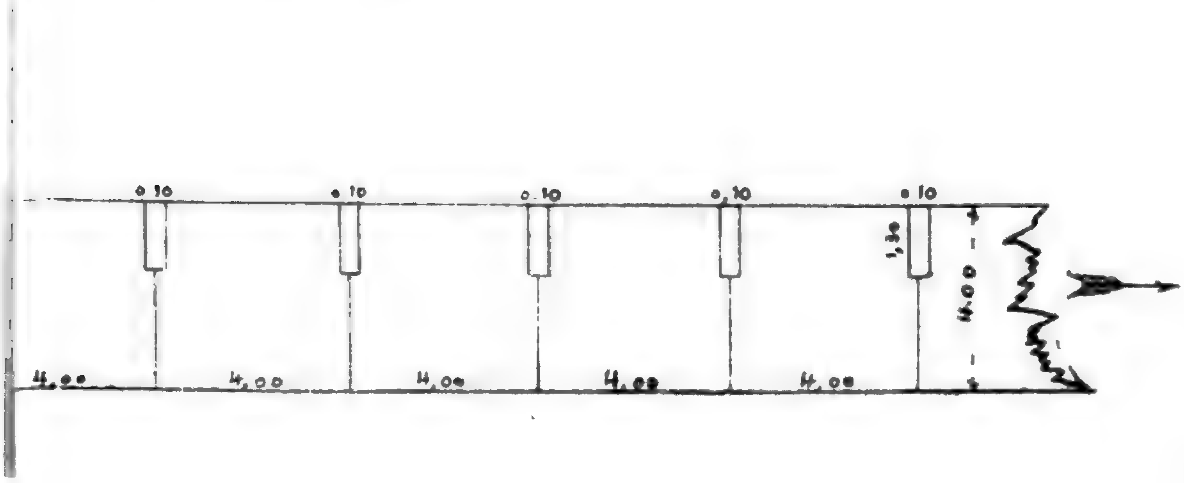
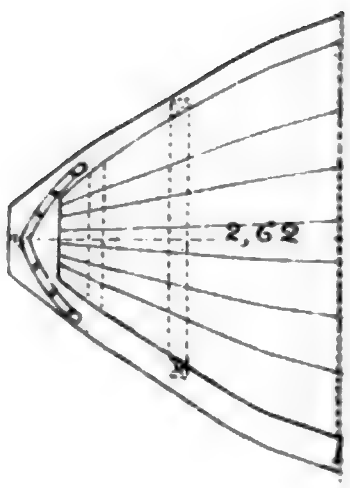
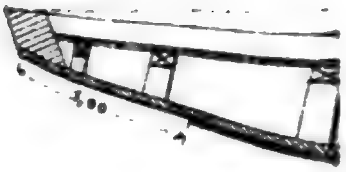


fig 6

ion des opérations pour l'ouverture d'une tranchée à la scie







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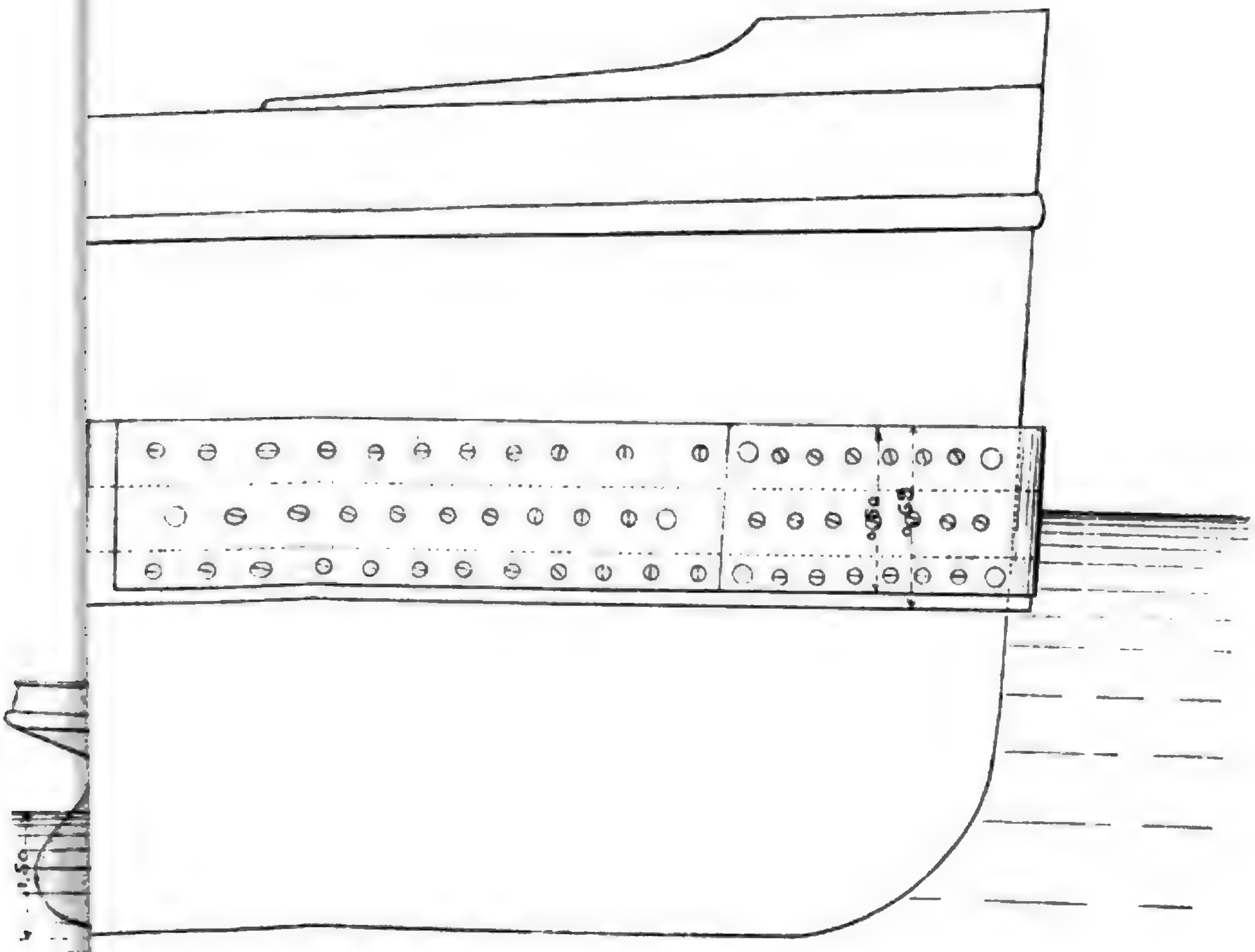
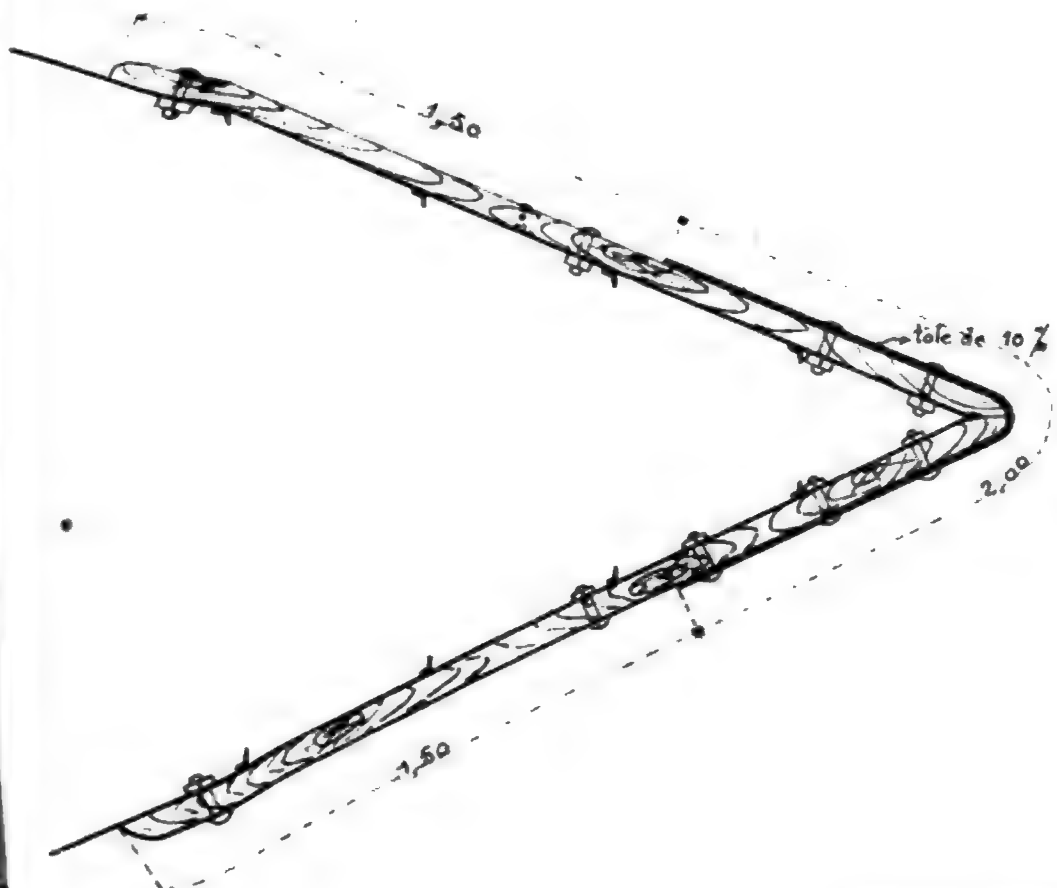
Photolithogr. procédé Mr. E. J. Asser.

Détails du brise glace (Echelle de $\frac{1}{25}$)

Elévation



Coupe horizontale



Photolithogr. procédé Mr E. J. Asser.

VIth International Inland Navigation Congress

THE HAGUE. 1894.

Various systems and methods for breaking and clearing away of ice. — Ice-breaking boats. — Explosives etc. — Results obtained. — Cost of plant necessary. — Working expenses

REPORT

BY

M. P. RIGAUX,
Ingénieur en Chef des Ponts et Chaussées.

Divisions of the Report.

Methods for breaking ice, engines employed under different circumstances according as they are required for inland canals and rivers, on the one hand, and sea-water canals and the estuaries of rivers and sea-ports on the other. The present report in accordingly divided in two parts.

We thought canals and navigable rivers should be included in the same chapter, simply because the waterways are of the same nature, although they may be subject to very different conditions from the point of view wich forms the subject of this article.

CHAPTER I.

CANALS AND NAVIGABLE RIVERS.

Various systems for breaking and clearing away ice.

The following are the different systems employed on canals:

a. River Currents.
b. Variations of level.
c. Use of ordinary boats as ice-breakers.
d. Special ice-breakers.
e. Explosives.
f. Axe and saw.

River Currents.

River currents should be especially utilised in canals where there are means at hand for introducing water from water-courses and means for clearing away water of low temperature. Generally river water is preferable to that of small streams; at any rate it is essential to guard against introducing water that proceeds from snow. These currents are extremely useful in annihilating the effect of the slight frosts which often precede or follow great cold; they may suffice as long as the temperature does not go below —6° or —7° C.

River currents also serve to prepare for the operation of the ice-breakers by wearing away and softening the ice and to hasten the breaking up of flakes of ice as much by melting as by rubbing them together as they flow. River currents also serve to clear away these flakes of ice.

This method is therefore of great service in certain circumstances and has the great advantage of costing nothing, but it is in reality a help and the practice of making use of it is very limited.

Variations of level.

At the same time that currents are produced the level of the reaches is often changed, and thus more energetic effects are obtained for risisting slight frosts and also for retarding the first action of prolonged cold. The occasion for employing this method is more doubtful when it is a question of thick ice. Some engineers consider it causes deterioration of the banks, endangers the solidity of certain works, badly built dams etc., and causing at the same time but few cracks in the ice. In every case to obtain results, repeated and violent oscillations are always necessary (from 0.40 m. to 0.50 m.).

After an accident, the Neuffossé canal having been invaded by the waters of the Lys, the level was suddenly raised to 0.60 m. above the normal to fall again 6 hours after by means of energetic draining to 0.40 below this level. The ice 0.20 to 0.25 m. thick was completely dislodged and it was useless to employ any other method of breaking it.

For certain purposes the only variation employed is to raise the water's surface to its original level, which has been lowered before the frost. In this manner the coating of ice is detached from the bank without damage and remains separated from it by a certain interval; the result of this is that the ice is more easily parted under the action of the ice breaker and the machine works more easily, the wedging of ice between the ice-breaker and the bank being rendered less frequent. This precaution is to be recommended in preference to repeatedly varying the level, when the banks are susceptible to damage.

Briefly, the method of varying the level of the water has at present but a limited application, and it is often impossible to resort to it on account of the presence of loaded boats in the canals, of the want of stability of certain dams or the damage it is liable to cause to the banks.

Boats used as ice-breakers.

When river currents and variations of level are insufficient, we must have recourse to ice-breakers. It is the only serviceable method.

For this purpose boats used for the transport of dredging materials, *margolats* and *toues*, whose bows and stern or bow only are but slightly inclined to the horizontal, are sometimes employed; or these boats are fastened together to make a broader track. Boats with bows nearly perpendicular are fitted with an *avant-bec* of strong wood (v. plate N° 1), the underside of which is lined with slide-bars of iron and which is slightly inclined to the horizontal, being supported against the lower end of the bow of the boat. The upper side of the *avant-bec*, which meets the bow in a plane inclined to the lower side, is also formed of a framework of timber and is firmly joined to the former, resting on the fore part of the gunwale of the boat.

When the bow of the boat is slightly inclined to the horizontal, a wooden frame work bound with iron bands is fastened against the bottom; it is suspended by chains from mooring pins and from two slanting beams placed lengthwise which rest on the bow of the boat, over which they project, and are firmly fixed to the ribs and prow.

Otherwise the bottom is simply protected by three or four rows of T irons placed longitudinally; in certain cases the thickness of the hull has been increased. It is also well to strengthen the ribs, for boats soon wear out with this work. At present with these machines it is not attempted to attack a greater thickness than 0.15 or 0.20 m.; it would be easy however to carry this limid further.

Boats armed under the bottom as well as under the bows seem to have more effect than those fitted with an *avant-bec* or shield; in fact the former can without inconvenience have the fore-part of the bottom resting on the ice and in this position the chiseling process is more energetic.

The *avant-becs*, frame-works and armour suitable for transforming boats into ice-breakers, cost from 150 to 750 fr.

Special ice-breakers.

The only special kind of ice-breaker we know of is that described in the Interior Navigation treatice of M. l'inspecteur-général Guillemain, Vol. II. p. 398 (v. pl. 2), which begins to be more widely used on several important navigable ways. These boats, in the conditions for which they have recently been established for certain purposes, weigh from 4 to 5 tons when empty and carry 2200 kilo of ballast in the stern; they are

2.60 m. broad in front and have pointed sterns; the bow and the stern are elevated. Thanks to this shape they easily raise themselves on the ice and at the same time the weight is brought to bear on the part that does the breaking. In a horizontal section, the width of the machine decreases towards the stern and this makes wedging in the ice less easy.

The bow is protected by posts in the front and a strong covering at the waterline; the plating is 5 m.m. thick on the sides and 7 m.m. at the bottom; the lower bottom is fitted in the middle with a strong iron which projects beyond the bow, bent at its outer extremity and about 2.40 m. long. This T iron is intended to facilitate the rolling movement and to bring the action of the ice-breaker to bear upon one point. The bottom of the boat is also protected by 4 or 2 bands of iron placed longitudinally, running the whole or part of the length.

Such an ice-breaker can now be built for 2000 fr. turned out near the workshop.

It would be an advantage, with a view to allowing the ice-breaker the more easily to lean over in order to rice on to the ice, while preventing it from getting too firm a grip, to give it a more pointed form at the stern in the lower sections and a fuller form in the higher sections.

Method of using ice-breakers.

The boat is generally weighted in the stern that it may act as much as possible like a great pair of shears with the fulcrum in the stern. This method of working the ice-breaker has no reason for being followed exactly under similar conditions by boats fitted with an *avant-bec* or ice-breaking frame-work in front. It is not necessary that these boats lean and advance on the edge of the ice sufficiently to touch their bottoms, because these bottoms are not protected. This class of boats break the ice by the weight of their bows, and under these circumstances the weight of the ballast in the stern is of less importance. Under some conditions even the bows are weighted.

Men, to the number of 4 to 8, generally place themselves on each side of the deck and give the boat a rolling movement. It is quite exceptional, except for ice-breakers of small dimensions or when the ice is thin, to make use of men for towing. Horses go either at a trot or the fastest pace possible, with as many stoppages as may be necessary not to overdo the horses. This work fatigues them terribly. From 2 to 24 horses are attached to each ice-breaker according to the power of the machine and the thickness of the ice. Generally not more than 10 to 15 horses are employed; when the team becomes very numerous the effective force of each additional horse becomes much less and the manœuvre becomes more difficult; therefore some engineers think more than 15 horses should never be employed. This consideration must limit the power of the different kinds of ice-breakers, and as, on the other hand, among those actually in use some employ at least 15 horses, it would appear to be useless to endeavour to make more powerful kinds than the strongest in use at present.

The kind to be adopted.

Boats converted into ice-breakers have up to the present been used for as rough work as the special ice-breakers; it cannot be doubted however that the use of the latter is safer, more convenient and gives better results. Nevertheless, the need of special machines would never be thought of but on waterways where it is of the highest importance to shorten the duration of the stoppages of winter. It is also to be observed that generally speaking the existence of thick and hard ice implies a temperature which has allready become, or which has not yet ceased to be, intense, and a very powerful machine would only break this ice for the fragments to reunite directly.

Therefore ordinary boats converted into ice-breakers can almost always be employed and these can between whiles be used as usual, instead of being left idle like the special ice-breakers except during the very limited periods of service for the removal of ice from the canals.

Besides, while at a cost of about 500 fr. a boat may be converted into an ice-breaker, and little boats may be built to serve as ice-breakers, a special ice-breaker costs at least 2000 fr.

Circumstances in which ice-breakers are of service.

The use of ice-breakers is generally not required in canalised rivers which have rather the character of rivers than canals. In fact in these rivers the ice is quickly carried away when it thaws and there is no risk of it's stopping long as in the smooth cold waters of canals. On the other hand in many rivers the water is stored by means of moveable dams which cannot be raised untid all ice has passed not only from the river but from its tributaries. It would therefore generally be a pure loss to clear rivers of ice. Besides the use of ice-breakers on rivers is nearly allways impossible, because we have not here to deal with a regular coating of ice as in canals, but more often than not with masses of ice welded together in various thicknesses and generally very strong. On the other hand when the river is wide, wherever the channel should leave the bank or change from one side to the other, towing would be difficult or impossible; in such a case a steamer would be necessary as in the maritime portions of rivers; but, whether for want of a sufficiently powerful steamer at one's disposal, or because all means of re-establishing navigation is recognised as useless, we have no knowledge of any case in which a steamer has been employed to clear away the ice from rivers inland.

On canals, on the contrary, the use of ice-breakers, which has only of recent years been developed, seems as though it should be most extended, especially on important waterways. Thanks to the use of these machines during the short periods of early or late frost they are sure to be kept open; also some days may be gained at the commencement over sharp or prolonged frosts and something like a week in the re-opening of navigation after the great thaw. It is difficult to fix a limit to the use of ice-breakers: the question not only depends on the importance but also on the nature of the winter traffic. Besides, in proportion as the need for breaking up the ice is less, by refraining from going to work until the resistance becomes less formidable, less considerable boats need be converted into ice-breakers and thus the expense of converting and working them is also diminished. Under these circumstances, considering the small cost of the conversion, it seems that few canals liable to freeze should be without ice-breakers that a slight probability of using them should be sufficient. It seems that this way of looking at it is the tendency of the present day, which seeks to carefully apply all possible means for giving satisfaction to the public.

On secondary water-ways, even when the general interest of traffic is not involved, but only some isolated boats are desirous of leaving which may be easily set free, an ice-breaker is not without use; it seems that in this case a free passage should be made for the boats, by calling together the bargemen interested to make the necessary effort both themselves and their horses. In other cases when the general interest is involved, and it is a question of re-opening au important waterway for transport purposes or a main route for inland traffic, where numerous boats are waiting all along the navigable way, their liberation should be effected at the expence of the service. Moreover, in this case the bargemen generally take in the situation and not only refuse to lend their aid, but demand a high price from whoever consents to hire them.

Expenses. — The expense of clearing away ice by means of ice-breakers varies greatly according to the machines employed, the thickness and hardness of the ice. It may however be said, avoiding extreme cases, that each square metre varying from 0.05 m. to 0.30 m. costs from 0.001 fr. to 0.006 fr. The most extreme prices cited outside these limits are 0.0005 fr. and 0.023 fr.

Clearing by means of explosives.

Explosives. — Choice. — The operation. — Results. — Quantities used per superficial metre or per cubic metre of ice.

Melinite or dynamite is used. Dynamite is more easily procured, but the use of melinite is surer. It has not been remarked that the effects produced by these two explosives are very different. Agents of the service or detachments of sappers and miners do the blasting; nearly all navigation agents have the habit of using dynamite. The general details of the use of these explosives are known and a detailed account of them has no place in the present report. It will be sufficient to mention that on the very rare occasions when explosives have been used on canals, it has been done to facilitate the passage of the ice-breakers: in this case the ice was first completely detached from the banks by a groove made lengthwise by means of axes. Sometimes the long strip of ice thus formed has also been divided into pieces about 7.00 m. long. In either case the cartridges were placed from 1 to 2 m. below the water and thus the ice was broken up. Explosions ander water however cause holes in the bottom of the channel and might be dangerous, on account of the shocks they produce, in places where the dams are not perfectly firmly set.

The use of dynamite placed on the ice has given no result. The fact however is well known. It has been attempted to improve this method by placing the cartridges at a short distance from one another in the grooves formed by the axe, by cutting out rectangles from the surface; slightly better results have been obtained, but the method is not practicable if the surface is large.

Generally speaking, the use of explosives is costly and is not applicable to canals and it seems to be abandoned. It can never be thought of except in places where the ice is exceptionally thick, as in some open places where it is more than 0.50 m., but even in this case it appears more practicable to sever the ice by means of an axe or haud-saw.

Clearing ice from rivers by means of explosives.

In rivers explosives are not generally used to hasten the recommencement of navigation, but only to remove accumulations of ice which are dangerous to constructive works or the rivers banks. We need not therefore occupy ourselves here with this subject, but we will give an instance which furnishes the best established data with respect to the quantities of explosives used to cause a breaking up of the ice. The scene was a navigable river. It was thought necessary to remove from the Meurthe a coating of ice which threatened to cause a blockage below Nancy. This coating, 0.30 m. thick, presented a surface of 30000 sq. m., and consequently a mass of 9000 cub.m. With the aid of a detachment of sappers and miners it was blasted with melinite and only 6.615 kilogrammes of the explosive were employed, or 0.22 gramme per sq. m., or 0.73 gramme per cub. m. of ice. The cost of the clearing away of the ice, every thing included, was 0.012 fr. per sq. m., or 0.040 fr. per cub. m. of ice; but in other cases on canals, 5, 6 and 8 grammes of dynamite have been used for a thickness approaching 0.45 m. As much as 25 gr. has been used in a case were the ice had a thickness from 0.25 m. to 0.35 m.

Such discrepancies should cause no astonishment, when it is remembered that many experiments have to be made to apply the use of explosives. At the commencement great quantities have been expended without much effect.

The use of the axe and saw.

The axe, and by preference the saw, which does not splash are only employed to a limited extent: to cut up the ice that is too thick to be attacked by ice-breakers (in broad fields of ice), or else to work in places where the use of the ice-breaker would be impossible or would offer inconveniences, as for instance in places where boats are drawn up which would be damaged by the violent action of the blocks of ice forced against them by the ice-breakers. The instruments besides are useeul to free constructive works.

Summary and conclusions.

The clearing away of ice for the special object of reducing the duration of stoppages by frost is little practiced except in canals and in some rivers which can be worked as canals.

River currents and variations of level are insufficient means, though useful at times, but they simplify the use of ice-breakers. The latter furnish the really effective method of clearing away the ice and are capable of breaking through a thickness of as much as 0.30 m. In most cases ordinary boats specially armed for the purpose are sufficient.

When the clearing away of ice becomes an absolute necessity on the main waterways, it should be done at the expense of the service and should be extended to the less important waterways, as soon as a collective, or even momentary, interest requires it, provided the bargemen offer their services, men and horses, gratuitously. Under these conditions in fact, the first expenses are very slight, the working expenses are practically nihil; but it is necessary to proportion the means to the end in view and consequently the expenses to the results.

The method of using explosives to clear away ice from canals is seldom practicable; they are reserved for the removal of thick and dangerous masses for the better safety of certain places and works.

The axe and saw can have but a very limited use, they may however often take the place of dynamite in the case of exceptionnally thick ice on canals.

CHAPTER II.

SEA-WATER CANALS. — PORTS ON THE ESTUARIES OF RIVERS. — SEA PORTS.

The Basse-Loire sea-water canal.

In the sharp but not persistent frosts (—13°) of the winter 1893—1894, the movement of vessels was able to reduce the action of the cold to the formation of ice only 5 mm. thick, which in no way interfered with the navigation. In persistent frosts the following means have been employed to avoid the cessation of navigation. As far as the lock chamber is concerned, communication with the Loire has been left open in order to make use of the tides; but this precaution has not been sufficient, the variations being too slow, and it has been found necessary to break the ice in the lock chambers and the channels leading to them by means of tugs.

Between the locks as soon as the water has begun to freeze, two and later on three tugs have been made to ply up and down the canal night and day. As long as the temperature did not go below — 7° the congealing of the flakes of ice did not prevent navigation, but as soon as it went down to — 10° or lower, it was necessary to join to the tugs two barges, coupled obliquely so as to occupy in the rear a width of 18 m.; a strong piece of wood maintained the distance apart astern and the fore part was covered with sheet iron; the apparatus thus formed and joined to two tugs was utilised to clear away the ice broken up by the tugs, and the continual movement of the apparatus prevented the fragments from freezing together once more. It was hoped that the ice might be thrown on to the banks, but this result was not realised. Perhaps it might have been done by subtituting for the outer vertical side of the barges a side like a ploughshare. All through the winter 1892—93, the first rigorous cold the canal has experienced, the above method was sufficient to keep the navigation open.

The expense occasioned by the breaking of the ice on the sea-water canal during the winter 1892—23 amounted in round numbers to 4100 fr., as appears from the following table:

	Working expenses.	Initial expenses.
(1) Coupling of barges	—	fr. 286.76
(2) 2 Tugs (1 of 15 and 1 of 75 horse-power) crews day and night, materials used . .	fr. 2200.-	
(3) Bargemen to steer the barges, 2 on each barge, day and night.	„ 806.40	—
Repairs to tugs (engines and hull)	„ 800.—	
Total . . .	fr. 3806.40	fr. 286.76
Grand Total . . .	fr. 4093.16	

The expenses referring especially to the clearing away of the ice, that is to say those incurred apart from the initial expense, amounted to fr. 3806.40 during 24 days over a length of 15 km. of canal, or rather less than fr. 11 per 24 hours per kilometre. Thanks to this expenditure the arrival at Nantes of 48 vessels, representing a tonnage of 15057 tons, has been assured.

In the winter 1893—94 the tugs were coated with sheet steel as far as 0.35 m. below the waterline. The repairs to the hulls were insignificant although the obstruction by ice in the channels where they were employed was considerable.

The estuary of the Loire.

During the winter 1890—91 the port of Nantes was freed from ice by means of dynamite where it was very thick and where it was thinner by means of *toues* and a steamer fitted with a special stem of joists and plates of iron. The port remained blocked from 15th December to 22nd January.

During the winter 1892—93, at the beginning of the cold the two tugs belonging to the government service at Nantes were set to work. These boats, built with the mark P. R., required by the „Bureau Veritas" for vessels navigating in waters blocked with ice, have managed to prevent the blocks of ice, that had become stationary with the turning of the tide, from freezing together in the port and mouth of the Loire. During the night of the 1st—2nd January a mass 3000 m. long formed below the port. The two tugs were up stream. As it would have been imprudent to attack the packice from up stream, the firm of Indret, situated down stream, was asked for the use of one of their boats. A steamer of 98 tons and 60 horse-power was put at the disposal of the government. At first, this steamer being without ballast and working on ice 1.50 m. thick, ran herself aground upon the ice and was only able to free herself at high water, but from this moment the steamer recommenced her work and continued at it day and night. After four days of persistent effort it was able to dig out a channel 50 metres wide across the pack ice. Unfortunately on the 6th January a fresh floe of 300 metres stopped in the narrow space below Nantes, where the first stoppage had taken place. The steamer from Indret could not attack the ice on account its thickness, but with the help of two tugs from the port, the ice floe was cut through on 8st january. Several small masses were formed subsequently in the narrow passage of which we have spoken, but these were easily dislodged with the help of a single tug. A mass of pack ice 1800 m. long had also to be dislodged from the mouth of the sea-water canal and this was accomplished with the help of one of the harbour tugs after the work up stream was finished. Until the ice finally broke up the two tugs remained one at the mouth of the sea-water canal, the other in the harbour ready immediately to dislodge the masses which attempted to form and thus to facilitate the disappearence of the floating blocks of ice. The final breaking up of the ice did not take place at Nantes till the 26th January.

The port remained blocked from the 2nd to the 8th inclusive. It has been impossible for us to obtain information respecting the expense.

The estuary of the Garonne. — Port of Bordeaux.

With regard to the port of Bordeaux we have only the account of the clearing of the ice in the winter 1890—1891.

The navigation had been interrupted for boats for six days, commencing the 15th January, but not for ships; they were only much inconvenienced. The flow of drifting ice past the port had continued without ceasing. The disappearance of blocks of ice took place very rapidly in the night of 20th to 21st Januuary and during the day of the 21st under the action of the flood due to the rain and south westh wind. But there was by the Bridge of Bordeaux a mass of pack-ice 600 m. long, 80 wide and in many places more than 1.50 m. thick. It was to be feared that fragments of this ice-floe, detached and carried away by the flood, might do damage to shipping. To attack the ice-floe one of the tugs used for dredging was armed with a breaking and protecting bow. A beginning was made up stream above the bridge of Bordeaux with flood tide so that the ice-flakes might be dispersed while passing through the bridge at ebb-tide. The operation lasted only three hours. A first attempt had been made on the 19th witha bow formed of two plates of iron 1 m. high and 2 m. long; the result was satisfactory, but a covering of iron or wood should have been fitted to the sides to resist the shock of the stationary ice and the large blocks of floating ice. Work was started at high water to avoid being overwhelmed by the ice drifting down stream, but a still greater inconvenience was experienced in consequence of this manœuvre, for the tug was jammed in the ice and could not free herself without difficulty. In cases of this sort it is better to work with the flood, which facilitates the relative displacement of the blocks of ice encountered by the steamer and the dispersion of the fragments detached.

Summary and Conclusions.

On the sea-water canal of the Basse-Loire and on the estuaries of the Loire and Garonne, it has been quite the exception to employ dynamite for the re-establishment of navigation; steamers of ordinary build have been sufficient, but it is desirable to protect them in the bows and sides.

It appears indispensable to operate under such conditions that the current shall carry away the broken ice as it becomes detached and keep the flakes moving if the river is covered with floating ice. In every case therefore it is better not to work at slack water, unless it is absolutely necessary, and when the ice-field completely bars the way it is essential to operate down stream with an ebbing tide.

Sea-Ports.

In the French sea-ports ice causes little trouble and is easily got rid of. The harbour service has the ice broken up in the docks and the approaches to the locks by means of the harbour tugs; as the tide goes down the blocks of ice are drawn towards the locks, whence they flow down to the sea.

This method of breaking ice is sufficiently delicate and requires prudence on account of the damage ice floes are liable to cause to constructive works and shipping, but especially to small boats. On the canals which connect the ports with the inland system, barges are used as ice-breakers. Sometimes also the level of reaches in the canals is raised from 0.50 to 0.60 m. by the introduction of salt water and the blocks of ice are sent down to the sea with the ebbing tide. This last method succeeds very well.

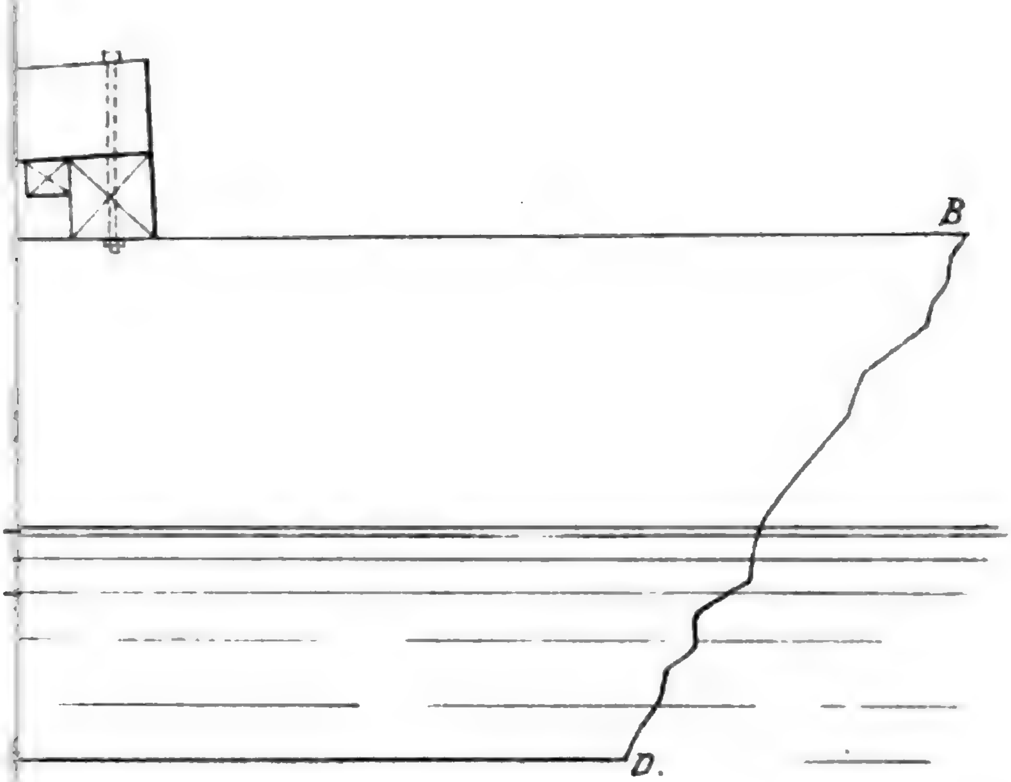
Charleville, May 14th, 1894.

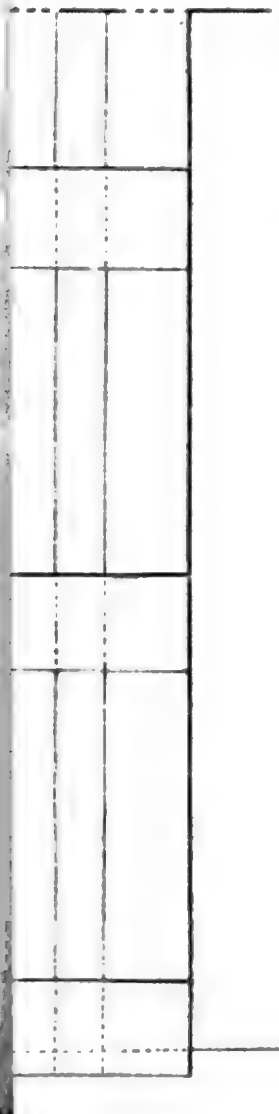
Translated by Francis A. Oliver.

Inscriptions des Planches	Inschriften der Zeichnungen.	Description of the Plates.
Brise-glaces constitué par un ponton de service muni d'un avant-bec.	Eisbrecher, bestehend aus einem mit Vorbau versehenen Ponton.	Ice-breaker made from a pontoon furnished with a fore-prow.
Plancher cloué.	Genagelte Dielung.	Nailed flooring.
Cornière.	Winkeleisen.	Angle iron.
Mollebande.	Gürtelband.	Girdle.
Tôles destinées à protéger les parties inférieures qui restent découvertes entre les fermes.	Schutzbleche für die unteren, zwischen den Gebinden liegenden unbeschützten Theile.	Sheets of iron intended to protect the lower parts which remain uncovered between the trusses.
Demi-plan.	Halbgrundriss.	Half projection.
Demi-largeur.	Halbe Breite.	Half width.
Coupe d'une poutre inférieure	Durchschnitt eines unteren Balkens	Section of lower beam
d'une ferme intermédiaire.	eines Zwischengebindes.	of an intermediate truss.
d'une ferme de rive.	eines Randgebindes.	of a border truss.
Coupe longitudinale en élévation du gouvernail.	Längsschnitt in der Richtung des Steuerruders.	Longitudinal section, viewed from stern.
Eau le bateau étant vide.	Tiefgang des unbeladenen Fahrzeuges.	Water, the boat being empty.
Chambre recevant au moment du travail 2200 Kilogr. de gueuses de fonte.	Raum, welcher bei den Arbeiten mit 2200 Kg. Gussstahl-Ganz beladen wird.	Chamber receiving while at work 2200 Kg. of pig-iron.
Bordage.	Flachgänge.	Planking.
Demi-coupe horizontale (le plancher enlevé).	Wasserpasser Halbriss (nach Wegnahme der Dielung).	Horizontal half section (the floor removed.)
Bordage.	Aussenhaut.	Planking.
Coupe suivant AB.	Querschnitt in der Linie AB.	Section following AB.
Fer plat.	Bandeisen.	Flat iron.
Détail de la rivure.	Art der Vernietung.	Details of rivetting.
Rivets.	Nieten.	Rivets.

Rigaux

ant-Bec. PL.I.

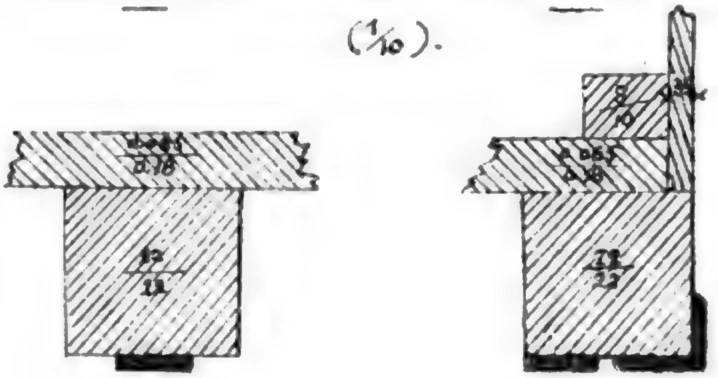




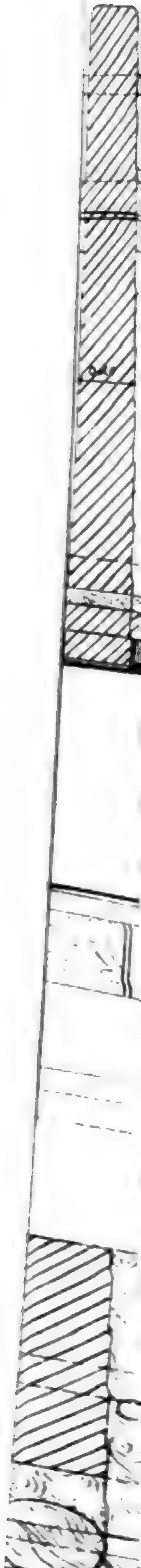
Coupe d'une poutre inférieure

d'une ferme intermédiaire. d'une ferme de rive

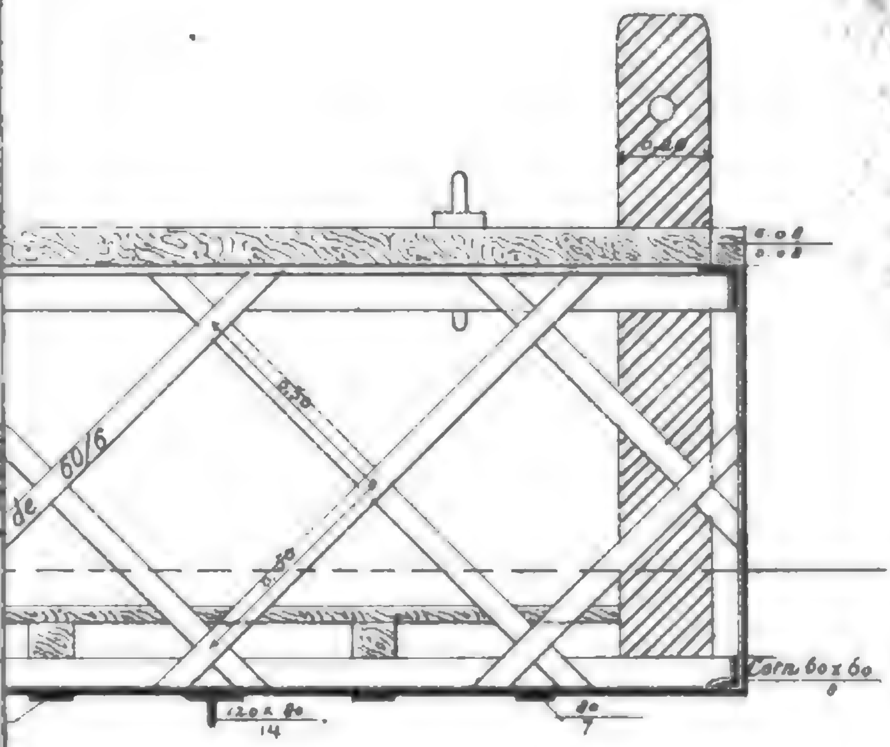
(1/10).



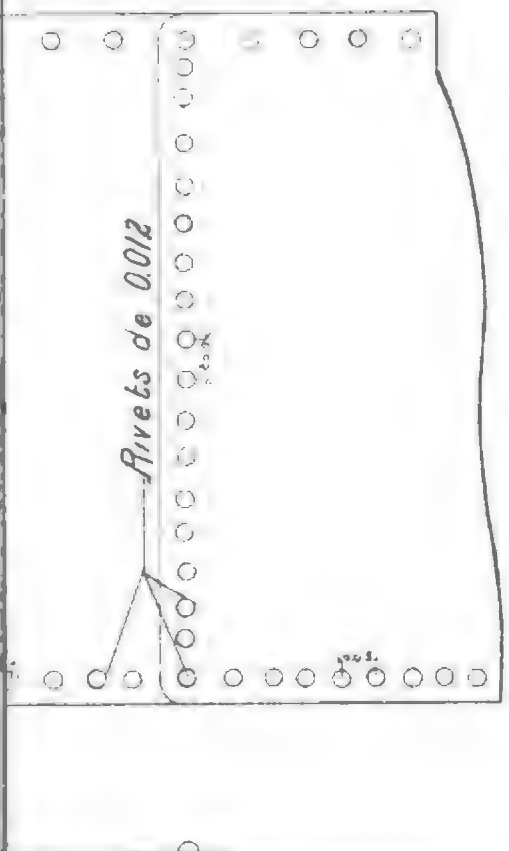
STEENDRUKKERIJ



Coupe suivant AB. ($^1/_{20^e}$).



Détail de la rivure.



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VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

3rd QUESTION.

The clearing away of ice in the estuaries of tidal and non tidal rivers.

BY

MAURICE DIBOS,
Civil Engineer, technical Inspector of the „Foncière-Transports",
Maritime and Fluvial Insurance Company.

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BY

MAURICE DIBOS,

Civil Engineer, technical Inspector of the *Fonciere-Transport*, Maritime and Fluvial Insurance Company.

Since 1870—71, or for the last twenty years, we have observed as well as our contemporaries in other countries that our regions, hitherto regarded as temperate, have been visited by quite exceptional cold which has caused the waterways to freeze nearly every two years; some maritime estuaries have been partially and our rivers completely blocked with ice, the thermometer varying in most cases between —10° and —27°, the average being —17° for districts reaching as far as 40° latitude.

The cold may last for a long time; thus at Paris, to mention only periods that were remarkable:

In 1870—71 there were twelve days continuous frost.
In 1871—72 there were twenty one days continuous frost.
In 1879—80 there were twenty eight days continuous frost.
In 1890—91 there were twenty days continuous frost.
In 1892—93 there were sixteen days continuous frost.

Without here going into an exhaustive study of the possible causes of these meteorological perturbations, which we think may be attributed to the progressive cooling of the earth's crust and to large spots on the solar disc during the winter solstice, we will confine ourselves in this paper to an account of the most suitable methods of opening up channels or basins of a sufficient width for vessels or boats to make their way through the ice and move freely in any direction, and freeing estuaries and the mouths of rivers from dangerous masses of floating fragments and ice-fields which form on these rivers and in their ports and outlets.

In many places in our country the inland navigable ways are frequented both by sea going ships and by river boats, and with regard to both kinds of traffic we will endeavour to give some technical and practical information to sea-men and boatmen whose craft might be overtaken by frost either on their journey or while lying at anchor.

It is known that immediately below zero the formation of ice takes place upon the surface of water of little depth. If the air is calm and the current very feeble, which is commonly the case in canals of small depth, long needles may be seen to shoot out from the banks, the piers of bridges, quays and the water-lines of boats at anchor, and to spread out and cross and join each other in every direction; the spaces between these needles disappear with the progressive solidification and a thin layer of ice will in a very short time cover the whole surface of the water. This layer increases in thickness under the influence of the frost and presents to the eyes of the observer a perfectly polished and transparent appearance.

If on the contrary the freezing is caused by a light breeze upon the surface, small crystals will cross each other; a sort of pasty mixture like half melted snow will then cover the water.

When the solidification is accomplished under these circumstances, the frozen surface is opaque and rough.

Streams and rivers from 3 m. to 8 m. deep seldom freeze, as far as we have been able to observe, above a temperature of about —10° or —15°. In still water at an average depth of 10 m., as in docks, it may happen during severe frost with a north or north-east wind that ice, already more or less formed, will thicken while the gates are closed between two tides, and reach, by the time ships and boats are able to go in or out, such a thickness that the movement of the port is so much hindered, if not totally stopped, that it may become dangerous, especially for entering ships when obliged to anchor in the outer harbour or to regain the roads.

The Marne, the Saône, the Yonne, the Meuse, the Loire and the Seine seldom freeze, as far as we have observed, at a higher temperature than —12° or —14°. However they carry down floating fragments of ice before this temperature is reached, perhaps at —4° or —6°. Before the frost attacks the whole river from bank to bank, numerous blocks of ice of various sizes and shapes are formed and are carried down by the current on account of their less density. It is well known that fresh water has the peculiarity that it reaches its greatest density at a temperature of 4°. If the liquid for some cause or other is cooled upon the surface, it continually descends to the bottom until all the water is reduced to the same temperature of 4°. The strata will then retain their respective positions, the coldest remaining at the surface. It seems therefore as if the phenomenon of frost must always take place on a free surface.

On the otherhand, in consequence of the saltness and agitation of sea-water freezing does not take place so readily and hardly occurs except in confined passages, in bays or estuaries or near coasts. In fact sea-salt lowers the temperature at which freezing commences and at which the maximum density is reached; the effect on the latter is far greater than on the former. Therefore on the sea ice forms to a great extent below the surface.

The denser the particles of ice become the more their dimensions increase in consequence of the solidification of other strata of water joining the first nucleus. As the bed of the water-course becomes more and more invaded the flow of the floating fragments, as they colide against each other and against natural or artificial obstacles, gets slower and slower. At a given moment some of the pieces stop and the floating mass comes to a stand-still. The frost then welds the pieces together and the stream or river is frozen over.

Navigation, which was getting more and, more difficult as the flow of ice increased, is completely stopped when the water-course is frozen over.

To retard the formation of the complete covering, means are generally taken on canalised rivers by moving the dams or sluices with the object of raising or lowering the height of the water. In this manner one or two days are frequently gained, but without any considerable advantage being obtained, for navigation really ceases some time before.

Petroleum poured on to the water-course, dock or estuary might be of considerable use for retarding the action of the frost, but for fear of the terrible fires caused by imprudence or accident from the use of this oil which floats on the surface of the water, it cannot be recommanded, except in out of the way or little frequented places or in pieces of water surrounded by dikes when a regular service is instituted to watch it continually.

In the Atlantic ports the docks are opened in order to clear the channels as well as the outer and inner harbours. For during hard frosts, with a temperature of —15° or —20°, the daily rise and fall caused by the tide is not sufficient to clear away the ice which, especially in the inner harbour, remains behind in the form of an ice-field which rises and falls with the tide without changing its position.

It was thought for a long time that ice always formed on the surface. BRAUNS, DESMARETS and DAGUIN are agreed upon the following theory: „When it is extremely cold the temperature of the water is less than 0° right down to the bottom in consequence of the movements which mix all parts of it together. Nevertheless the solidification is prevented by the agitation of the molecules of the water. But where the liquid is kept motionless by gravel and all sorts of *débris* nothing prevents it from freezing. Each particle of ice formed in this way serves as a nucleus upon which the frost continues to act in such a manner that the flakes of ice increase in size and raise the water of the river.

„The ice-flakes are retained upon the bottom, either because they are welded to fixed portions or because the gravel mingled with them is heavy enough to keep them down. When the ice-flake is thick enough for the pressure of the water to raise it, it rises to the surface" (1).

We have often had the opportunity of convincing us by observation of the exactnesss of this theory. Moreover many morcels of ice bear unmistakable traces of their origin of formation on account of the gravel, grass, sea-weed, mud or shells which they enclose and carry away at the moment when they are freed from the bottom and rise to the surface. After this ice formed at the bottom has floated away the mark of it can be clearly seen upon the bottom, which appears to be dredged.

The consistence of the pieces of ice is still comparatively feeble, it is more like a mixture of crystals of ice and impurities, such as slime gravel, sand, grass, shells and mud (boue) separated by water, from which it acquires the name of ***bousin*** (slush or rotten ice).

In winter periods of complete and momentary thaw succeed periods of frost; during the former pieces of ice frozen together part asunder and break up into fragments if they meet with an obstacle which stops or opposes them. These accidental stoppages on the part of the frozen mass in movement are most dangerous and liable to cause floods and do much damage to property near the banks and to ships and boats down stream. Stopped in this way and pressed against each other the ice-flakes finally freeze together and unite, thus creating a formidable and threatening barrier. By referring to the experiments of TYNDALL the theory of the phenomenon of recoagulation may be explained by the mechanical theory of heat. If a piece of ice is heated, a part of it is liquified and its volume reduced by so much. Therefore if by some mechanical action, such as pressure, this latter effect is produced, the caloric necessary for causing the fusion is reduced proportionally. From the foregoing it may be deduced that at the temperature of melting ice, which is the temperature at which ice forms, ice-fields may still form having a resistance equal to those formed by the original frost at temperatures less than zero.

The breaking up of the ice takes place either when the temperature rises or when heavy rain or snow increases the volume of the water of the river, or when spring tides coming after neap tides progressively raise the level of the water and the movement of the latter in unprotected places will finally dislodge the fields of ice and the ebb-tide will carry the fragments out to sea.

We must remember that with a thickness of 0.04 m. the ice will bear men singly walking on planks and that a thickness of 0.12 m. or 0.15 m. is strong enough for carriages and horses.

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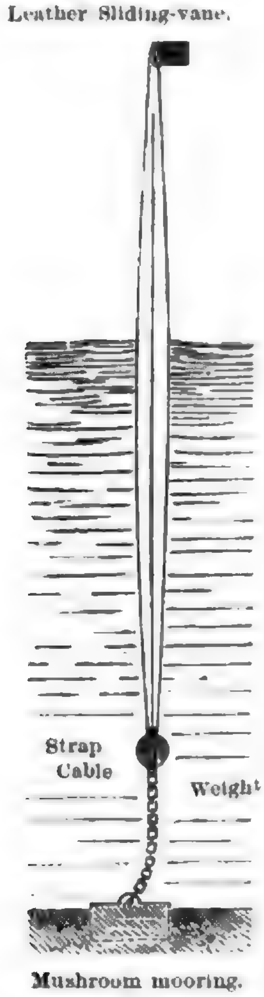
(1) DAGUIN. Tracte du physique, vol. II.

Fig. 1.



Tho flow of ice-flakes on rivers, especially in their mouths and in estuaries where the navigable channel is marked, is the cause of the greatest inconvenience on account of buoys and marks which sustain with difficulty the incessant assaults of the floating ice and which, if they are not carried away or destroyed, at any rate strain upon their moorings or anchors. The result is confusion as to the route and accidents become possible.

This state of things might be remedied by substituting for ordinary buoys in the mouths of rivers or in maritime estuaries, which are liable to be rapidly overwhelmed with ice, floating poles or buoys quite elliptical in shape, the major axis being 7 m. to 15 m. and the minor axis 0.40 m. to 1.00 m.

The end constantly under water is fitted with a swiveling strap to which the free end of the chain attached to the mooring or anchor is joined; the weight of this chain, or a suitably calculated weight, would keep the poles half under water and always in a vertical position. The part that shows above the surface should be painted an appropriate colour (fig. 1).

When the floating ice comes against it, the pole leans over, offering no resistance and being in no way liable to damage, and will appear again as soon as the floating mass of ice has passed.

This system is recommended in America by the U. S. Light-house Board, and by M. HORTA, Naval Engineer (1). for the port of Antwerp.

Technical engineers, naval officers or captains of merchant-men may therefore be called upon to solve the following problems:

α. The clearing away of ice on stagnant water in order to obtain as wide an area of open water as possible;

β. The dislodging of an ice-field on running water and the opening up of a channel, so as to ensure the general breaking up of the ice without accidents and the re-establishment of navigation;

γ. The freeing and protecting of vessels and boats when ice-fields have formed and during the general breaking up of the ice.

Without thinking for a moment of laying down fixed rules we will examine these questions with respect to their frequency of occurrence, and we will endeavour, guided by a certain amount of experience, to furnish some information which we hope may be of service in this special kind of work.

In the case of stagnant water it is first necessary to disengage the boats and ships frozen up in the ice-field, for their hulls are subject to considerable pressure and there is a risk of their being distorted or of their bottoms being seriously damaged or crushed.

If the ice is not more than 12 cm. to 15 cm. thick it may be attacked by carpenter's axes and hatchets by cutting grooves perpendicular to the sides of the ship or boat and gradually freeing the hull by clearing away the blocks about a metre long that have been cut away by means of hanspikes, boat-hooks, bars and levers. In this manner the vessel is freed on all sides and a sort of basin of water is opened up which should be freed of ice morning and evening and during the night if it is necessary.

For breaking the ice that has a tendency to re-form round the ship's side the best way is to use poles with baskets of wicker-work on the ends which can be shaken about from the ship's side, or from the ice-field.

For cutting up the ice-field saws with long thick blades and a broad set are used with success; they are similar to those used for cutting stone; a double handle is fixed at one of the extremities of the blade, a hole is made in the ice to admit the saw and after having weighted the end of it with a stone or piece of lead or other heavy body, it is worked in the usual way. The best results are obtained by slanting the saw at an angle of 20° or 30° to the plane of the ice, as by this means it bites better and the weight, while determing the suitable pressure of the blade, also automatically facilitates the descending stroke.

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(1) *Notice sur la bouée d'hiver*, American ice buoy, *et son application au jaugeage des fleuves*, by M. HORTA, Naval Engineer, Antwerp (1892).

Chisels or cutters may be used, such as workmen on railroads employ in cutting bars of iron, for dislodging or breaking fragments; but as the workmen when the frost is very severe cannot hold these implements, and find if difficult to work with gloves on, the best plan is to prepare specially stakes of hard wood 2.50 m. long and 4 cm. in diameter which are fitted into the socket of a sharply pointed piece of bar iron.

From unknown causes some parts of the ice-fields vary from the average thickness, and the efforts of the men above the workings cause unexpected ruptures in the ice around the open cuttings; this circumstance is a source of danger to the men employed. It will therefore be essential that men should be on the watch around the ship or boat with coils of rope and buoys ready in case of accident. As soon as the vessel is sufficiently disengaged, a specially fitted up boat may be brought to the open space, either a wherry or some flat bottomed boat which will be stationed close to the workings and will help to push back the blocks of ice, and will be able to come to the rescue immediately if necessary.

Near the men on the ice joists or planks will be laid down and one or two boat-hooks will be handy. When necessary the workmen will be required to wear life-belts and a line some 15 metres long will be lashed to these belts and the free end will be held by an assistant either on board the boat or on the ice-field several metres away.

If the ice round the vessel is 20 cm. thick it may be necessary to employ explosives. Still the use of them is rather risky on account of the shocks transmitted by the mass of ice to the vessels frame especially if it is built of metal. Before using powder it is desirable first to cut away by hand perpendicularly all round the ship a belt of ice about 30 cm. wide so as to isolate the hull as much as possible from immediate contact with the ice-field.

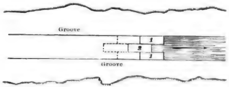
For this the saw may be used with advantage; at some distance away an open space will be made into which the detached blocks will be drawn, the first being pushed under the ice and cleared away as soon as possible so as to make matters more easy for the workmen. In support of the use of the saw as we recommend it and by means of which we have obtained excellent results, we will mention a fact noted by the much lamented Admiral Pâris: „In 1855 a vessel was surrounded by ice at Kil-Bouroum in the mouth of the Dnieper. The attempt to break the ice by means of axes was ineffectual; they made little impression on the ice and left in the groove that was first obtained broken pieces which deadened the succeeding blows. The vessel was freed by sawing away the ice, an operation which was however effected in spite of unfavourable circumstances, for as there were no proper implements at hand pieces of toothed sheet-iron from 3 mm. to 5 mm. thick had to be used and these were fitted with shot at one end and a handle at the other."

As soon as the vessel is disengaged a constant watch must be kept on the water all round to prevent it from freezing again. If the vessel is provided with steam-power the boilers may be heated and by means of pipes attached to them jets of steam may be played against the sides and the freezing action may be stopped where there was still contact between the hull and the ice.

To break up an ice-field on running water it is first essential to open up a channel which will by preference be effected where the velocity of the current attains its maximum. The thickness of the ice is generally less in this place. The nature of the banks and quays will also be examined with a view to observing the points likely to be attacked by the current if the water-course or estuary is sinuous. The cutting of the ice will be commenced down stream. Care will be taken to ensure that the blocks of ice detached and carried away by the current may find an easy means of exit; in fact it is necessary to guard against the formation further on of another ice-field composed of the pieces of ice carried down stream. When necessary the blocks that are not too large will be hauled on shore by trains of horses and the crews of the ships. To facilitate the operation of getting them out of the water they are slid along joists, planks, rails or beams to which a slight gradient is given, they are slung in a chain of suitable dimensions; it is safer and works quite as quickly as a holdfast or hook.

In order to create these channels by mechanical means the following system (fig. 2) might be adopted with success. It is in our opinion after some experience the most expeditious method.

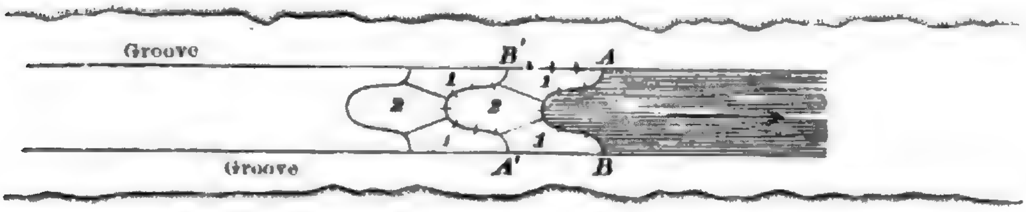
Fig. 2.



Two grooves parallel to the banks are cut at a distance apart fixed upon for the width of the channel. The rectangular blocks 1 and 1 are first cut away from the ice-field and then 2. The detached rectangles are pushed away with boat hooks if the current is not sufficient to carry them away, as is often the case.

For channels for the creation of which explosives are used or which are very wide the horse-shoe form (fig. 3) may be adopted and the row of cartridges may laid along the line A B or A B′, A′ B.

Fig. 3.



It appears to us difficult to establish any mathematical rules with respect to width to be given to the channels across the ice-fields; we can only draw attention to certain points, as the work is modified according to the locality, the current, the width or the sinuosity of the water-course or estuary.

According to the remarks we have made we think that the channel to be cut through the ice-fields on rivers of an average width of 60 to 150 m. should be about 12 m. to 20 m., for very wide rivers and estuaries, 200 m. to 600 m. and more, it might be 80 m. to 150 m. or more if in either case it is a question of removing a bank of ice similar to those which formed on the Seine, the Loire and the Saône during the winter of 1879—80.

As we have said above in the case of stagnant water, the method of clearing away ice that is not more than 12 cm. to 15 cm. thick is the same for running water for similar thicknesses. The axe, the saw, levers and crow-bars may be employed with success.

It will be well to make use of a large roughly and strongly built boat the bows of which should have a double coating of wood outside and this should be covered with sheet-iron about 5 mm. to 7 mm. thick. A certain number of men are put on board and from the shore by means of a rope the boat is hauled upstream straight against the edge of the ice-field. The men on board give it a heavy pitching movement by simultaneously moving from stem to stern and they make it roll by going first to one side and then to the other.

The undulation which is transmitted below the ice breaks off lumps from the edge. The boat is moved forward as the ice-field breaks away and the men armed with boat hooks assist the blocks of ice to get into the current which carries them away.

This craft may also be weighted by ballast or by men and after attaching to it a long hawser to which six or ten horses are harnessed, it may be towed along at a trot. The boat strikes against the ice and splits it and slides on to it cracking and breaking it by its weight.

On the Marne during the winter of 1892—93 by this method with the help of a gang of ten bargemen armed with boats we were able in twenty hours divided into two shifts to cut a channel 502 m. long and 14 m. wide through an ice-field 13 cm. to 15 cm. thick. and we were able to save three boats whose total burden amounted to 780 tons and was worth fr. 600,000, from a bank of ice upstream which touched the bottom and was composed of pieces frozen together and piled up to a thickness of 5 cm. and would certainly have carried them away. The cost of this operation amounted to fr. 450 We were inclined to use charges of Favier powder if it had been necessary, either before or during the general breaking up of the ice, to demolish the ice-bank. We had calculated the charges in the proportion of 3000 grms. for an average depth of 1.50 m., which at the explosion of the mine enabled us to count upon holes of a radius of about 4 m. We will return later to the question of the use and choice of explosives.

When there is not time enough or it is impossible to create a channel sufficiently long for the ice to flow away without difficulty, ships and boats should be protected in the bows and sides when anchored alongside the bank and on both sides when anchored in mid-stream with a sort of double covering of joists 2 m. long and 0.04 m. thick, joined together vertically, two thirds of the length of which are under water. The moorings must be increased and chain cables should be used in the proportion of one to four. Metal cable resists far better the blows and shocks of the blocks of ice, the roughness of which has no effect upon the strands, where as hemp cables are rapidly worn away, cut up and broken by the numerous jagged floes drifting down stream. There should be men on board armed with marlin spikes, spars or planks with which they can push back the blocks of ice. If the vessel is a steamer the steam should be kept up after the ice has been cleared away astern so that if the moorings or anchor cables give way resistance may be made to the ice by driving the ship ahead, at full steam if necessary, and trying as long as possible to avoid getting broad-side on to the drifting ice, to stem the current and gain time enough to moor to the shore or to change to metal moorings or double hawsers.

Under dangerous circumstances when the ice has been breaking up and there has not been time enough to open up a channel we have fitted the boat with an ice-breaker made of deal joists 20 cm. square and 10 m. long firmly laced together in the shape of a *V*; this woodwork floating in front of the boat and lengthening the sides threw on each side the floating ice which attacked the bows of the boat.

In such circumstances for four boats in a line surprised by a very hard frost, —16° (ice having been floating down the river for five days), we fitted across the bow of the foremost boat at an angle of 20° a series of piles 20 cm. in diameter and 6 m. long, which descended 1 m. into the bed of the river and 2.90 m. apart. We joined these piles together by means of horizontal joists 0.04 m. thick and 3 m. long, nailing them with long nails and forming slide-bars of them. The tops of the piles stood out about 80 cm. and the height of the slide-bars was 75 cm. above and 52 cm. below water, together 127 cm. We used the deck of the boat itself for erecting the ram and the two first piles upon which a platform was constructed *ad hoc*. For the sake of prudence all the tops of the piles were lashed to a hawser made fast on shore, and struts made of two pines 15 cm. in diameter and 9 m. long, resting on the fore-shore did hold the piles 1 and 3 in position. The convoy was saved from the floating ice which arrived six hours after the completion of the work which had lasted a day and a night, and during which Wells's light was used.

The average thickness of the blocks of ice coming down with the current was 20 cm. to 25 cm. and they measured from 7 to 12 sq.m. After the first blow against the top of the slide-bar these blocks following the diagonal direction that had been given them, passed the line of boats the crews of which had only to keep a look out and have their bars, etc. ready at hand.

The piles and joists had been put up with the understanding that the timber that was damaged should be paid for.

Besides the indemnities on this account, the carriage backwards and forwards of the apparatus and the labour, the cost of the operation amounted to fr. 788. These six boats together contained a cargo of 1400 tons which was valued at fr. 1,100,000.

For ice-fields 0.75 m. to 1 m. thick steam-boats built specially for the purpose may be employed with success. It is clear that for this work we require powerful boats the fore-parts of which are strengthened with some resisting metal such as steel. These vessels will be fitted with two or three water compartments in the bows and stern which may be rapidly filled or emptied to obtain the greatest variation in draught when it is required to do so, both fore and aft.

Before the steamer attacks the ice the compartment in the stern is filled with water so as to raise the bow which is built with a sharp curve like a spoon so that it can glide upon the ice. If however the ice resists, the shock of the boat, the weight by means of reservoirs is concentrated in the bows and the frozen surface is broken by the extra strain.

Among the most powerful specimens of this class of vessel the *Murtaja*, a steamboat built at Stockholm at the works of Bergsund for the Finnish Government, may be mentioned as a type. The *Murtaja* is intended to keep the port of Hangö open throughout the winter where the ice attains an average thickness of 0.70 m. This ramming boat easily breaks through the resisting masses and moves safely amidst the enormous blocks of ice which it breaks off. The *Murtaja* has a length of 47 m. between uprights, its width is 10.97 m., depth 7.00 and draught astern

5.80 m.; its displacement is 1070 tons and it is driven by a compound engine of 300 horse-power with a surface condenser. The vessel is divided into air tight compartments the two endones of which form the reservoirs necessary for the mechanical rocking movement. The hull is covered with iron armour 254 mm. thick at the water-line and 158 mm. lower down. For working against ice of an average thickness of 0.70 m. the normal speed of this steamer is 10 or 12 knots an hour (1).

The repeated shocks made by the rushes of these boats, besides breaking off considerable pieces, make cracks in the ice-field which extends for a long distance and greatly facilitate the general breaking up.

While we are occupied with this subject we should mention that in December 1890 the General Inspection Service of Navigation on the Seine was begged by the Sub-Commission of Navigation of the Municipal council of Paris to take measures to discover if it was possible with the help of armed-boats and by using the flotilla of omnibus-boats to break the ice formed on the river at Paris and to keep it open. This interesting question was studied with great care by the Inspectors of Steam Navigation on the Seine together with the engineer of the Compagnie des Bateaux Parisiens.

As regards the special management of each boat the following are the *desiderata* arrived at. The hull should be covered, besides the special ice-breaking arrangements, with a coating of wood 0.05 m. to 0.06 m. thick rising 0.90 m. above the water line and descending 0.60 m. below it; this covering being indispensable to protect the iron plates of the skin against the pressure and rough edges of the ice-blocks which might perforate or indent thin hulls.

The most economical solution was the employment of separate pannels 4 m. long strengthened with joints or hinges and fixed to the boat by a catch on the upper end. The frame work of different sizes being made to fit the shape of the vessel. The pannels on the bow were plated with iron 0.02 m. thick. The solidity of the whole framework was ensured by chains running round the pannels and by cross-beams placed upon the deck. The approximate cost of this arrangement amounted to fr. 800 per boat including a sort of cage to protect the screw from blocks of ice which by their weight are large enough to rupture the propeller.

It was essential to find out how many boats would be required to keep the channels free, in order that the efforts made might be crowned with success.

Each boat would have to limit its field of action to a distance of 500 m. with a minimum width of river of 100 m. Each boat therefore would have to clear and keep free an area of 50,000 sq.m.

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(1) In America paddle-boats similar to this are used.

The river in Paris 12 km. in length, would therefore require twenty four boats.

The entire reach, 25 km. in length, would have required fifty. The expenses for the crew, per day and night of work, would amount to fr. 72, engines of about 80 horse-power burn 2 tons of coal per 24 hours which cost fr. 108, oil and sundries come to fr. 5, thus bringing the total up to fr. 185. The daily hire of fr. 100 paid to the municipal Administration must be added to this sum and the total will therefore amount to fr. 285 per boat.

This estimate was calculated for ten days of continuous frost, so that the cost amounted to fr. 87,600 for twenty four boats and fr. 182,500 for fifty boats, not including the case of the possible loss of one of these boats, worth about fr. 50,000, for which the city of Paris would have been responsable.

The conclusions arrived at in the report of the Inspectors of Navigation on the Seine were unfavourable to the carrying out of this project, partly on account of the expense it would have incurred, and partly on account of the indifferent results to be expected owing to the sharp bows of the Bateaux Parisiens which would have attacked the ice of an average thickness of 0.30 m. like a great axe; the effect is consequently only felt over a restricted area and in the direction in which the maximum resistance is met with. Moreover, as regards manoeuvres the boats would not be able to turn, would only be able to follow on a zigzag irregular course by making sharp turns and going astern to fetch each new tack. The official report adds that the cold may be so intense that the broken pieces of ice dislodged by the bow froze together again a few metres astern and prevent the backward movement of the boat which will thus be hemmed in and become useless or lost.

Whatever method may be adopted for the formation of the channel, the latter always has a tendency to become blocked once more by the action of the frost. To avoid this serious inconvenience it is well to make a rowing-boat or steam-launch go up and down or better still in the case of channels of great length, a steamer; a paddle-boat by preference.

We will briefly in the following pages investigate the use of explosives in the form of charges placed upon or below the surface as well as the methods of firing them. M. Lambert, chef de bataillon of engineers, mentions in his report that at Saumur in 1879—80 they fired a continuous line of no. 1 dynamite cartridges fixed end to end on rods for a distance of 150 m., using 100 kilo of the explosive for each operation. The bank of ice presented a thickness of 1 m. and after the explosion it was observed that there were numerous fissures from which cracks departed in every direction and a furrow of an average depth of 0.40 m. directly below the rods supporting the dynamite (1).

The left branch of te Seine at Bougival is barred by the mill and weir of Marly and a little way up stream by a foot bridge intended for the service of the lock of Bougival. In 1879—80 masses of broken pieces of ice heaped up till they formed a formidable bank in this confined region, sunk, when the thaw and general breaking up of the ice took place, a large number of boats and barges anchored in this branch where they had originally sought safety. It was essential to take means to prevent these desasters, and according to the report of captain De Félix, military engineer (1), they employed at Bougival in 1890—91, on the small branch of the Seine which was covered with ice 0.30 m. thick a chain of *pétards* of mélinite or Favier powder at a distance of about 1 m. apart and fixed by connected fuses. The *pétards* were first placed in a groove made by hand at an average depth of 0.10 m. the tamping was effected by filling in with snow. After the explosion there was a cutting 3 m. broad which constituted a small channel that was rapidly widened.

In these two examples the results obtained may be considered as very satisfactory. The fissures are not always made so successfully and to obtain satisfactory results it is well to use a continuous line of *pétards*. This was done in the case of an ice-field which formed on the 10th January 1891 above the bridge of Conflans-Andrésy. The existence of this bank of ice became very dangerous for the bridge as well as for that of the railway and the weir of Andrésy situated down stream. In fact at the general breaking up of the ice such a barrier might for a moment have stayed the flow of water and ice coming from up stream and caused them to spread out with an irresistible impetuosity when the pressure becoming excessive it might have overcome the resistance of this barrier. It involved the destruction of constructive works and numbers of boats moored along the shore and imprisoned in this spot. A detachment of sappers under the command of one of our colleagues, Lieutenant Tardi, was sent from Versailles in order to effect the distruction of the icefield with the aid of civil engineers.

Before attacking the ice near the road bridge it was first necessary to free the reach between the latter and the railway bridge, where the ice might interfere with the descent of the pieces broken off from the ice-field. This coating of ice, 0.10 m. in thickness, was dislodged by means of rows of melinite pétards (135 grms.) 1 m. apart fired by connected fuses. The blocks of ice detached were then cut up by a gang of bargemen working with axes and engaged for the purpose.

As soon as this passage was open the destruction of the main ice-field was commenced. The first thing was to clear away the first bay from the right shore occupying about a quarter of the width of the river, where the ice having a thickness of 0.50 m. still presented the form of a bank of ice within about 100 m. of the bridge, although over the other three quarters it was 1 m. thick.

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(1) *Revue du Génie*, September—October 1891.

It is understood that operations were commenced down stream; a cutting was made in the ice by means of axes, so as to dislodge a rectangular block about 10 m. long (in the direction of the current) and 15 m. broad. To effect the lines of fracture five grooves were cut with axes in the surface; in the centre of each of these a *pétard* of 200 grms. of Favier powder was placed, laid flat at the bottom and covered with a tamping of sand. These *pétards* were fired by connected fuses of melinite and a Bickford match and caps of fulminate of mercury.

The results after the explosion were perfect and the fragments from the block were carried away by the current. The most serious difficulty was met with in making the cutting through the ice-bank proper. We have already said that the average thickness of the bank in this place was more than 1 m., and the chain of cartridges was insufficient to completely sever the frozen mass. Regular mining chambers were dug to a depth of about 1 m. and were charged with 2500 grms. of Favier powder in a sufficient number of cartridges joined together on rods and covered with a tamping of sand. The whole was fired by electricity (detonators of fulminate fired by electric percussion from the river-shore). The effect of the explosion reached to a distance of 30 m. and made a hole with a radius of 3 m. which was filled with the *débris*, and even broke the ice beyond this radius, so that the sappers and bargemen with boat-hooks detached large blocks which they drew into the current. Underneath these fragments enormous quantities of rotten ice were carried down.

When these pieces of ice were too large they were broken by a *pétard* of melinite placed upon their surface the fuse of which was lighted from the bank.

In the course of a week a channel about 70 m. wide opened up over a distance of 300 m. The quantity of ice cleared away amounted to 10,000 cub. m. and about 160 kilo of explosives were used.

The general breaking up of the ice took place during the night of the 24th 25th and not one of the numerous boats moored along bank was injured, while the constructive works remained intact.

We have given a detailed account of this operation because in our opinion it represents the method of employing charges on the surface for the special work of which we treat in this paper, and because the clearing away of the ice at Conflans was effected under the most unfavourable conditions which an engineer or naval officer can meet with.

From what we have already said and from our own practical experience, it is evident the use of charges on the surface gives but comparatively freeble results.

The results are far better if the charges are placed under water like torpedoes, as the effect is increased by the effect of the excellent tamping formed by the ice which doubles at least the effect of the water tamping.

Let us first see what are the exterior effects of a submerged charge. When fired, the immediate consequence of the sudden deflagration of the powders is the production of a great quantity of vapour and gas at a temperature of about 2400°. This elastic body distends and drives back the molecules of water in every direction, by which means a space is created in the water. This chamber has momentarily the form of a sphere described from the powder as centre with a radius which at first is very limited.

Effects of two kinds then occur, the one exterior the other interior.

This enormons bubble of gas which has formed in the water strictly obeys the laws of gravitation and rapidly rises. The sphere representing the chamber of gases is transformed into more or less oval form and the new body has its major axis vertical. The dimensions of this oval become larger and the free surface of the river or the sea rises into a dome. Then a great segment of a sphere appears and the oval bubble bursts the summit of this segment and finally escapes into the atmosphere.

It can be understood that if upon its arrival at the surface the oval bubble meets with a layer of ice which prevents it from expanding in the air, the energy of the gases which form it spends itself against the resisting covering of ice which intercepts its diffusion in the air and that the pieces of ice are at once dislodged over a wide area and are shattered wherever less resistance is offered to the submerged charge.

On the other hand the interior effects of the explosion under water consist in a violent commotion which is transmitted throughout the neighbourhood of the charge. This vibration which is felt to a considerable distance is caused by the expansion of the gases resulting from the explosion which rapidly strike and drive back the medium in which they have developed. Water being an incompressible medium transmits the shock and pressure in every direction. This concussion is propagated through the water at a velocity of 1400 m. a second and gives rise to a wave the force of which decreases in proportion to the square of the distance. It is therefore desirable in these circumstances to place the charge a little below the ice so as to make full use of the natural tamping formed by the incompressible liquid in order to obtain a wave capable of dislodging the frozen surface while at the same time the energy of the gas developed is not hindered from effecting the rupture of the ice, and economy in the use of the explosive is not forgotten.

As these operations sometimes take place in the neighborhood of boats it is necessary to limit the extent of the charges to a comparatively restricted radius, for if is important not to forget that this interior commotion, due to the force of the expansion of the gases is far from being inoffensive to floating bodies. Within a certain distance of the centre of the explosion, a distance that may be called the radius of rupture, the resulting wave blows all vessels to pieces; beyond this zone and within other limits it crushes or injures them.

It is evident that if these phenomena are satisfactory as regards the breaking of the ice, the case is different for the hulls of boats or ships which may be within the radius of rupture. Therefore submerged charges cannot be used for the clearing away of ice in the neighbourhood of vessels without running considerable risk; therefore charges placed on the surface or mechanical operations would have to be used.

It appears to us difficult to determine the exact limits of the dangerous zone created by an explosion of a charge below water and these laws cannot be condensed into algebraical formulae; the charge, the medium, the thickness of the ice, the distance of the floating bodies from the charge, are so many factors of a most variable nature.

It seems to us risky to proceed otherwise than *by experience* to find the radius of this dangerous circle. However it may be observed that the lateral effects of a charge below water are less than the vertical effects.

With the explosives employed or furnished by the military engineers, at the request of the civil engineers, the expense was comparatively heavy. For the requirements of commerce and industry, in which the interests of private individuals demand the most complete economy, it has been sought to use cheap explosives which may nevertheless produce results almost equal to those caused by the warlike material. Such are the safety powders invented by Colonel Favier of the Engineers which are nitro-hydrocarbonates (nitrate of ammonia and nitro-napthaline).

Dynamite and nitro-glycerine have the serious inconvenience of freezing at 8° which at temperatures of —10° to —16° makes the transport of them most dangerous. It is generally supposed, quite erroneously, that it is absolutely necessary to thaw dynamite to use it with effect. Besides, the operation of warming it is attended with the greatest danger and requires much time. It may be exploded by priming the cartridges with caps of fulminate (2 grms.).

The melinite employed by the military engineers at the expense of the state or of private persons comes to fr. 7.50 the kilogramme. It is therefore an expensive explosive.

The dynamic effects of Favier safety powders respond greatly to the various needs of the special work for the clearing away of the ice with which we are occupied.

These explosives have the advantage over dynamite of being insensible to frost and over melinite as regards the price which is fr. 3.50

the kilo. Like melinite these powders may be moved without any special care. They are not regarded on railroads as dangerous goods provided they travel apart from the fulminate priming. Favier explosives which do not explode under the action of flame and resist violent shocks only go off under the influence of caps or detonators of fulminate of mercury. They have therefore the same advantageous properties as melinite. We recommend them. The detonators for Favier safety powders are made with a minimum of 1 gr. of fulminate of mercury in each.

The priming of the cartridges is the same as for dynamite cartridges; a hole is made in the centre of the powder contained in the middle of the cartridge, after having raised the edges of the outside paper which envelopes the latter, and the cap is burried in it. The match is next fixed to the paper by means of a string. The blasting cap should be placed in a whole cartridge in order te have a greater initial energie. There is no fear of if going off by contact with the match as in the case of dynamite, for the Favier powders are as we have already said very difficult to explode. The blasting cap may therefore be driven in as far as it will go; by this means it is better preserved against shocks of the ramming by dry tamping.

The preservation of Favier powders only requires by way of precaution that they should be stored in dry places, that boxes should be on shelves and the cartridges not opened. It goes without saying that if these cartridges are opened or broken and remain long in this condition they become unusable, like all other explosives containing nitro-hydrocarbonates and especially nitrate of ammonia.

The explosive seldom misses fire, but the detonators and fulminate caps which have been allowed to get damp may do so; it is therefore absolutely necessary to keep the caps perfectly dry and to avoid in manipulating them striking them or letting any hard foreign substance mingle with them, the least serious result of which would be to set the cap off in the hands of the operator and thereby seriously injuring him.

For charges under water ordinary black powder may also be used. We made use of it some years ago to break ice of an almost uniform thickness of 21 cm. in a basin having an area of 3025 sq.m. We took some bottles which go by the name of Saint-Galmier which have a capacity of about 0.95 litres and in which 600 grms. of black powder was introduced. These were corked with ordinary corks perforated to admit the waterproof Bickford fuse one end of which was buried in the powder. The cork was covered with putty and was firmly united to the connecting fuse and the neck of the bottle. An iron wire forming a ring was fastened to the bottle which was hooked, after the free end of the Bickford match had been lighted to a boat-hook fixed to the end of a pole about 6 m. long. A hole aslant was dug in the ice by means of axes and picks a little behind the part it was wished to break. This pole was pushed under the ice as nearly horizontally and as far from the hole as possible, the bottle still hanging on the end of it. The length of the Bickford fuse was calculated to take a minute to burn. The part above the surface was terminated by a strop to which a bag of sand was attached to keep the pole as nearly horizontal as possible and prevent it from getting underneath the ice.

The explosion dislodged the ice over a radius of about 6 m. and cracked it for double that distance. Equally satisfactory results could be obtained in running water. It seems that this system, or one very like it, is used by the Germans. We were not aware of this fact when we began with the experiment above mentioned.

To fire the charges a slow match also known as a safety or Bickford fuse is employed. It is a continuous thread of powder tightly packed in a tube 3 mm. in diameter which is contained in cord which is itself composed of two coverings of tow or tarred thread rolled in a spiral one across the other in opposite directions. The outer diameter of the cord is about 5 mm. Such is its general composition. The water-proof Bickford match which should be used by preference for clearing away ice is covered with gutta-percha or caoutchouc. This slow match burns regularly, even at a depth of 10 m. below water, at a speed of 1 m. in 90 seconds.

Before using this contrivance it is always essential to take care that it is in good condition and especially that it is not crushed in any places and that the continuity is nowhere broken. It is well to burn in the air 1 or 2 m. of the packet of Bickford match that is to be used and thus to test beforehand the speed at which it burns.

This waterproof fuse may be left under water for several days. It is therefore excellently well suited for firing charges under water for the destruction of ice-fields.

In order to fire a charge a piece of Bickford match is cut off long enough to allow a person to get far enough away before the explosion, calculating the combustion at the rate of 90 seconds to the metre. The end of the Bickford match is driven as far as possible into the cap of fulminate so that it may touch the fulminate. The cap thus primed is driven into the charge which is previously placed in some closed and water-tight receptacle, care being taken to cover the Bickford match passing through the neck of the receptacle with a little Chatterton wax (1). We have just said that for firing the charges under water, about a minute after they were let down, we simply used very fat putty for sticking the Bickford match to the orifice of the receptacles. This putty was preserved from the cold, until it was used, by being rolled continually in the hands of a barge-man. This primitive method succeeded very well.

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(1) Chatterton wax is sold in sticks which must be kept in a cool place. It is a mixture of gutta-percha, tar and resin. Before using it must be softened by heat. The flame of a candle may be used care being taken to keep it at a suitable distance from the powders and fuses.

The coating is applied and worked with wet fingers till the requisite shape is obtained.

The use of the Bickford match is in our opinion the best pyrotechnic method of firing mines.

Of the various methods of firing by electricity the best, according to the atmospheric conditions met with in winter, is not to use a battery that requires a solution that is liable to freeze. On account of this great inconvenience it is preferable to use a magnetic-electric apparatus for firing the priming. The instruments which fire by percussion act well in all weathers and weigh little.

This apparatus constructed by Breguet consists of a U shaped magnet formed by several layers of steel blades; round the two poles are fixed coils which are rolled up in such a manner as to produce the greatest effect and are connected with the circuit which contains the priming. An armature of soft iron, touching the poles, turns round a hinge parallel to the line of the poles; it is governed by a bent lever ending in a button which is struck smartly with the fist; the armature rapidly moves away producing an induced current in the coils; but a spring attached to the bent lever touches a fixed screw and keeps the coils short-circuited during the first part of the rotation. It is only at the end, when the extra-current is added to the induced current, that the spring leaves the screw and sends the whole current into the circuit of the priming. The regulating of the fixed screw is therefore a matter of the highest importance. It must be made in such a manner that the spring shall not leave the screw until the armature is no longer in contact with the magnet, but immediately after this moment is arrived. A so called safety bolt, which is only opened when the priming is to be fired, renders the armature immoveable and prevents accidents.

Two connecting screws are placed in the lower part of the apparatus. Between these two screws the priming should be arranged in tension, that is to say the wire from the first screw should end in one of the wires of the first cap; the other wire of this is connected with one of those of the second cap; the second wire of the latter to the third and so on until the last, the second wire of which should be connected to the second screw of the apparatus for regular trains, which we will treat of later on. If only one charge is to be fired the wire of the first connecting screw ends in one of the wires of the cap, the other end of which is joined to the second wire which is fixed to the second screw of the apparatus. We have already said that the priming should be placed near the centre of the charge of powder or driven into the middle of the cartridge the deflagration of which it is intended to provoke.

The induction current produced being a current of high tension the distance between the primings, and consequently between the mines or cartridges, and the apparatus may be neglected and may be considerable without inconvenience. The apparatus on a small scale weighs 2.75 kilo and is able to fire two primings; the medium size weighs 8.50 kilo and fires eight primings, and the large size weighs 10.50 kilo, and fires twelve primings. The medium size seems to us to be the most useful.

It is however essential to take great care of the connections between the conducting cables and the primings to ensure contact; it will be well to polish by scraping them with a knife the uncovered ends of the wires to be connected; the connections should then be isolated with gutta-percha cloth, gold-beaters skin or paper in order to obviate their contact with the ground or the ice.

Care must be taken not to pull hard on the wires of the primings for fear of pulling them out or of injuring the priming. We have already pointed out that fulminate priming should always be kept free from damp (1).

With regard to the thickness of the wires it is well to use the following sizes:

The red copper wire intended to connect the primings should be five tenths of a millimetre and should be covered with an isolating substance (gutta-percha) two millimetres thick. The red copper wire intended for the transmission of the main current will be from seven to nine tenths of a millimetre in diameter and should be covered with cotton besides the isolating envelope of gutta-percha. It is more convenient to use double conductors, that is to say two isolated wires placed side by side and bound round with cotton.

Electric priming is made like ordinary fulminate priming, but with the addition of a certain quantity of gun-cotton in which a spiral of platinum that becomes red-hot when the current passes through it, is buried.

As regard the calculation of charges we might here mention the rule adopted hy miners:

To obtain in kilogrammes the charge of an ordinary mine of which the line of least resistance h *is given in metres, cube this length and multiply the result by a coefficient* g *which depends on the nature of the ground.*

This rule is expressed by the following equation:

$$c = gh^3.$$

It is easily understood that for ice there is much uncertainty in the choice of the coefficient of a medium that is so variable. In a very remarkable military study on the breaking of ice (2), Captain BERTRAND of the

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(1) With the above mentioned apparatus Abel's electric detonators may be used.

(2) Revue du Génie, September-October 1891.

Engineers says that if ordinary mines are used in pack-ice in such a manner as to form a connected line of holes, the formula $c = gh^3$ may be tried, where, c being expressed in kilogrammes and h in metres, g is equal to 1 for powder and to 0.5 par dynamite, and he adds that this formula supposes that the tamping is effected under good conditions.

We think that during hard frost and with the use of powder the ice may be treated as bad masonry, and in this case $g = 3$, which for a mine placed at a depth of 1.50 m. in ice of a consistence equal to that of inferior masonry would give a charge of 10.10 kilo of powder per mine and, at a depth of 1 m., 3 kilo.

For Favier powder the charges are calculated in the following proportions:

1. For 1 in weight of no. 1 dynamite take 1 in weight of no. 1 Favier powder;
2. For 1 in weight of no. 1 compressed powder take $^1/_3$ or $^1/_2$ of no. 1 Favier powder;
3. For 1 in weight of no. 1 powder in grains take $^1/_4$ or $^1/_3$ of no. 1 Favier powder.

It is essential not to crush the cartridges in the tamping or their density will be increased.

The following figures indicating the sensibility of the Favier powders under the action of fulminate of mercury in proportion to their density, show how important it is not to increase the density of the explosive in the mine.

At a density of	1	the explosive requires a cap containing	0.75	grms. of fulminate.
»	1.10	»	1.25	»
»	1.20	»	1.50	»
»	1.25	»	2.00	»
»	1.30	»	3.00	»
»	1.40	»	3.50	»
»	1.45	»	4.00	»
»	1.50	»	5.00	»

It is evident that if by an inadvertent compression an explosive at a density of 1 is given a density of 1.50, instead of a cap of 0.75 grm. of fulminate, 5 grms. would be required.

To fire several charges or mines at the same moment it is necessary to regulate the transmission of the fire, that is to say to arrange it in order that from the point of lighting to the charges or mines, the length of the Bickford match may be in such proportion that the charges do explode simultaneously. The following arrangement (figs. X, Y, Z) may be adopted, avoiding right angles and very sharp bends which would retard the regular progression of the combustion of the Bickford match, which it will be remembered is at the rate of 1 m. in 90 seconds. The greatest care will be taken that in the connections the pieces of the

Bickford match in contact shall be perfectly united and covered over so that there may be no risk of the continuity in the fuse being broken.

Fig. 4.
X.

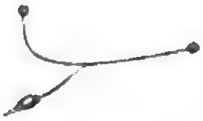


Fig. 5.
Y.

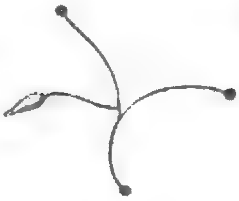
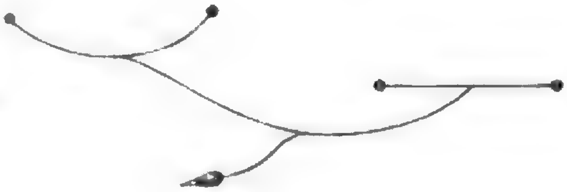


Fig. 6.
Z.

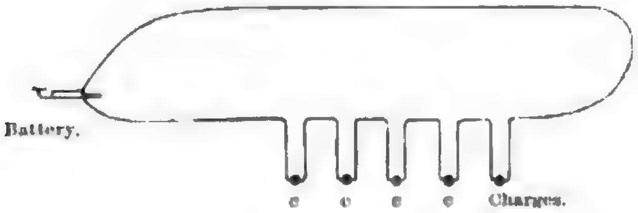


For causing simultaneous explosions by means of electricity two methods may be used:

1. The method of completing the circuit when the priming is placed in the same circuit and the same current passes through the priming of all the cartridges. This system is the most usual in clearing away ice.

Example:.

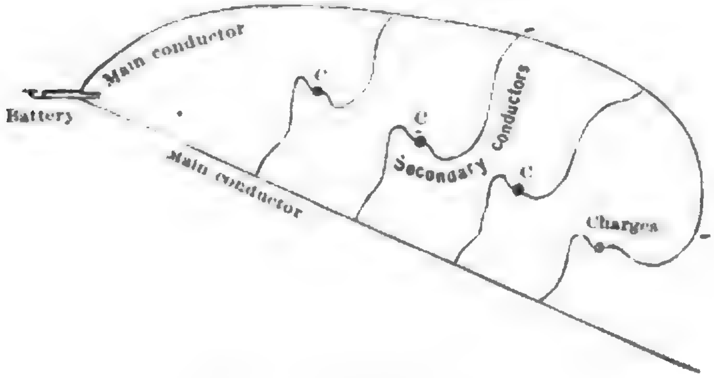
Fig. 7.



2. The method of secondary circuits, when each priming is placed in a particular circuit formed by secondary conductors which end in the priming and which are connected to the main wire by forming a succession of secondary currents.

Example:

Fig. 8.



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VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

3rd QUESTION.

MEANS FOR PREVENTING ICE BLOCKADES.

BY

A. A. BEKAAR AND J. NELEMANS,
Waterstaat-Engineers.

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INTRODUCTION.

The stoppages of navigation caused by ice occasion to trade and industry a greater loss perhaps than that caused by the periodical stoppages necessary for the execution of repairs; because the stoppages by ice occur in a manner more or less unexpected or unforeseen and all the navigable ways of a commercial or industrial centre are at the same time and to the same degree subject to it.

For canals leading to the upper part of a river the question of stoppages of navigation by ice will offer but subordinate interest, because at these times the river will no longer be navigable.

The same will be the case with canals frequented only by inland boats; the latter are in fact for the most part built of wood and are therefore the more liable to damage from the ice; besides, they have not the necessary means of traction or propulsion.

Although the question of reducing by artificial means the continuance of ice blockades may be of importance for inland navigation canals, it is however necessary in the first place to deal with sea-water canals, for which the question of preventing stoppages or reducing their continuance has a special importance. In the following pages we shall give a brief account of what was done in this respect on the sea-water canals from Amsterdam to the North Sea and from Ghent to Terneuzen during the winter of 1890—91, concluding with certain remarks which appear to us to be dictated by experience.

The following data concerning the principal periods of hard frost since

1828, according to observations made at Amsterdam, may have some interest for the question which occupies us:

Winter of	Beginning	End	Lowest temperature	
	of the frost.		Date.	Degrees F.
1828/29	Dec. 22nd	Jan. 26th	Jan. 23nd	3
1838	Jan. 7th	Jan. 20th	Jan. 19th	2
	Feb. 3rd	Feb. 22nd		
1847/48	Dec. 19th	Jan. 28th	Jan. 19th	7
1850	Jan. 8th	Jan. 25th	Jan. 21st	4
1855	Jan. 16th	Feb. 27th	Feb. 17th	5
	Dec. 13th	Dec. 24th	Dec. 21st	9
1860/61	Dec. 25th	Jan. 17th	Jan. 16th	8
1864	Last days of Jan.	Last days of Mar.		
1870	Jan. 19th	Feb. 23rd		
1870/71	First days of Dec.	Feb. 15th	Feb. 11th	7
1879	Dec. 1st	Dec. 28th	Dec. 9th	11
1880	Jan. 11th	Feb. 5th		
1890/91	Dec. 6th	Jan. 22nd	Dec. 30th	5

CANAL FROM AMSTERDAM TO THE NORTH SEA.

The description of the canal is given in the visitors' guide of the Congress, it is therefore useless to repeat it here.

Ever since 1880 measures had been taken to prevent or reduce as much as possible ice blockades on this canal. A company called „de IJsploeg" (the Ice-breaker), formed in 1879, built an ice-breaker which was firmly attached by bolts, chains and joists to one or two tugs.

The ice-breaker built of plates and angle irons was about 14 m. wide over its whole length; in the stern there was a sort of open space about 10 m. long in which the tugs fitted; the total length was about 20 m.; the height was 0.17 m. at the bow and 2.43 at the stern.

By making use of water or cast iron ballast, the fore part could be made to slide on to the ice or under it. The broken pieces were cleared to one side, either under the ice whence they returned for the most part to the channel, or on the ice left on each side of the channel.

The weight was 84 000 kg.; the cost of its construction amounted to 26 280 florins.

Boats which passed through the canal in time of frost were protected against damage from the ice by plates of iron about 1 m. wide suspended at the water line.

The shape of the ice-breaker would not allow of manœuvring in every direction when the ice was thick. A channel only 14 m. wide was made in which it was not possible for boats to pass one another or to lie to.

The siding was formed by two openings in the Hembrug (bridge of the railway from Amsterdam to Zaandam, at 7 km. from Amsterdam).

The speed of steamers, ordinarily from 150 to 250 m. per minute, was reduced to 100 m. during hard frosts. This precaution was taken in order to prevent the obstruction of the channel formed by the ice-breaker by large floes of ice on the broad fore-shore of the canal, which might become detached from the banks.

The results obtained were satisfactory in ordinary winters, when the thickness of the ice was not more than 20 centimetres Above all the damage done by blocks of ice to the screws of the tugs used to propel the ice-breaker was a cause of great inconvenience, while the tugs available were not always powerful enough. For ice between 10 and 20 centimetres thick two tugs of 50 horse power were generally sufficient.

The working expenses varied greatly; they amounted at times to 400 or 450 florins per diem, everything included.

The company which worked the ice-breaker in the interest of navigation derived its revenue from a tax of $1^{1}/_{2}$ cents per cubic metre on sea-going vessels navigating on the canal between the months of November and March.

By these means the company had, at its dissolution in 1890, rendered real service to navigation, although it cannot be denied that in severe winters these means were not sufficient.

The winter of 1890—91 furnishes us with a proof of this.

Putting aside the unimportant frost of November, the 6th of December may be taken as the commencement of the frost which lasted almost without interruption until January 22nd.

The thickness of the ice was:

Dec. 21st: at Ymuiden 29 centimetres, at Hembrug 34 centimetres;
Jan. 20: at Ymuiden 29 centimetres, at Hembrug 58 centimetres.

It then diminished gradually to 25 or 30 centimetres, a thickness which it had on the 26th of January. After this day the ice-flakes were carried down to the sea by the tide.

The port of Ymuiden was always accessible for boats, but sometimes not without great difficulty, especially for small boats for which the help of strong tugs was indispensable.

On the 7th of December the ice began to offer some inconvenience to small boats, and on the 10th the management of the old company, which had been dissolved the year before and was about to hand over its plant to the new company not yet constituted, thought an effort should be made to remedy the situation by setting the ice-breaker to work. Unfortunately after the 14th the screw of the tug was so damaged that it was unable to continue and a smaller ice-breaker was not able to open a sufficiently large channel.

At the petition of some merchants of Amsterdam on the 17th of December two ironclads (monitors) were set to work by the Minister of the Marine to try and break the ice; one starting from Amsterdam was very soon stopped by the ice, the other one starting from Ymuiden broke its screw and became powerless after a run of 7 km. Navigation remained completely interrupted until the evening of the 19th. On this day the steamer „Sea-horse" broke the ice alongside the man-of-war near Ymuiden and commenced the journey to Amsterdam, followed by five other boats and the man-of-war, while on the 20th and 21st nine steamers near Hembrug which had been waiting for the ships bound for Amsterdam to pass, made the journey thence to Ymuiden. For the passing of the boats near Hembrug channels were opened by hand and a small ice-breaker.

From the 21st to 28th of December navigation was possible without great difficulty.

On the 28th of December the steamer „European" after leaving Amsterdam was soon stopped by damage sustained by her rudder, while on the 29th near Buitenhuizen the „Amstelstroom" had to lie to on account of her screw being broken. The passage of other boats had become impossible and the severe cold from 29th to 31st of December coinciding with these disasters, a new and serious interruption to navigation had commenced.

On the 2nd of January a company was formed at Amsterdam to further the general interests of navigation. This company gave its first care to re-establishing the interrumpted navigation.

It was proposed to make a channel by hand and with the aid of a steamer, the „Koningin Emma", stopped near Ymuiden by the ice, which would perform the functions of an ice-breaker. The ice was divided by furrows cut with an axe into rectangles of 3 or 4 m. by 7.50 m.; when the ice had been cut up thus for a certain distance the steamer succeded in making a channel about 15 m. wide as far as circumstances would permit; it was followed by other boats.

The passage was made very slowly and the operations were very costly; for these reasons the Minister of War was asked for the assistance of the torpedo service to break the ice by means of explosives. This help was granted and after a few trials a commencement was made on the 10th of January.

As before the ice was divided into rectangles; the charges of powder of from 4 to 10 kg. were lowered in earthen pots 1 m. or 1.50 m. below the ice in the middle furrow at distances of about 10 m.

The explosion was effected by an electric machine of Siemens and Halske.

In most places the holes formed had a diameter of from 5 m. to 15 m. whilst the ice was cracked to a distance of 5 or 10 m.

The steamer pursued her course through the broken ice after the explosion of a few mines.

Altogether 838 explosions were made using 5026 kilogrammes of gunpowder.

The passage of the „Koningin Emma" from 0.8 km. from Ymuiden to Amsterdam (25 km.) lasted from the 3rd to 25th of January; the steamer was followed by twelve others.

On the 23rd of January the thaw commenced and on the 25th navigation was re-established.

The expenses of the company during the winter 1890—91 had exhausted all its means; they amounted to 45000 florins, not including the cost of the gunpowder etc., which amounted to 5250 florins.

After the experience of the severe winter of 1890—91 the company hastened once more to establish more energetic means to prevent stoppages of navigation by ice. It sent a commission to Stettin to study the question and received a very favorable report on the ice-breakers employed on the Oder and Stettiner Haf.

The company caused two ice-breakers to be built in 1893 by the „Stettiner Machinenbau-Actiën-Gesellschaft Vulcan" at Bredow-Stettin, the principal dimensions of which are the following:

	Ice-breaker. No. 1.	Ice-breaker. No. 2.
Length	43 m.	32 m.
Width	10.80 m.	8.50 m.
Depth of hold	5.30 m.	3.90 m.
Draft while breaking the ice	5 m.	4 m.
Engine	Triple expansion.	Compound.
Power indicated	830	350
Number of boilers	2	2
Heating surface of each boiler	165 sq. m.	130 sq. m.
Steam pressure	11 Atmospheres	8 Atmospheres.
Expenses	fl. 191 400.—	fl. 81 600.—

The cross section of the ice-breaking boats is almost oval; the keel slants considerably so that the fore part of the boat rests on the ice and breaks the ice-crust by its weight; the fragments for the most part disappear under the ice at the side, but return into the channel by the movement caused by the screw. The highest point of the screw is at a depth of at least 1.25 m. below the waterline.

In severe winters the boat will be used (1) only to break the ice in the canal, (2) to facilitate the approach to harbours and docks and to render assistance to vessels.

The company furnished a capital of 350000 florins for the purchase and working of the ice-breakers; the cost of maintenance, sinking of capital etc. are estimated at 27000 florins a year; working expenses during frost for (1) are estimated at 135 florins a day, for (2) at 90 florins a day.

The company receives yearly subventions to the amount of 27000 florins for maintenance etc. and 9000 florins at most for working expenses. The Netherland Government, the Province of North Holland and the city of Amsterdam contribute one third of these sums respectively.

The winter of 1893—94 did not furnish a favorable opportunity for making decisive experiments respecting the results that it is hoped to obtain on the Amsterdam canal, for the ice broken was at most only 0.20 m. thick; the boats made only a few journeys and, moreover, the staff was not sufficiently practised. It is probably for this latter reason that the manoeuvres, especially going astern and turning round, offered certain difficulties, although the ice-breaking boats of Stettin, absolutely identical with those of Amsterdam, execute these manoeuvres perfectly, even in ice of considerable thickness.

The crossing and avoiding of other craft was effected without difficulty.

CANAL FROM GHENT TO TERNEUZEN.

Description.

The entrance or outer harbour of the canal on the left bank of the Scheld, 19 km. above the port of Flushing and 65 km. below Antwerp, opens on the pass of Terneuzen indicated by buoys and light-houses.

The latter immediately branches off into the east and west outer harbours, each of which lead to a lock at Sas.

Above these locks each of the two branches of the canal, which go round the town of Terneuzen and join each other 0.8 km. above the west lock, is provided with a swing bridge.

From the junction of the two branches the canal is straight for a distance of 5.5 km., at the end of which is the swing bridge of the railway from Ghent—Terneuzen to Sluiskil. There is another swinging bridge 0.30 km. further on for carriages.

The course of the canal between these two bridges forms a curve and the passage of boats at ordinary times is sufficiently difficult and requires precaution.

Between Sluiskil and the East lock, or the new lock of Sas of Ghent, the distance is 6.4 km. In this portion the canal is but slightly curved.

The east dam, 1.4 km. above this lock crosses the Dutch-Belgian frontier, which follows the course of the canal for a distance of 0.6 km., so that 2 km. above the lock the whole canal is in Belgian territory.

The old branch of the canal, passing by the town of Sas of Ghent, joins 0.5 km. below this and 0.4 km. above the new lock.

Below the new and above the old lock the two branches ot the canal are provided with a swing bridge.

Sea-going ships, with few exceptions, make use of the west lock of Terneuzen and the east lock of Sas of Ghent, each of these being 12 m. wide. Between these locks therefore there are four swing bridges, three of which have a span of 18 m. and one (that below the lock at Sas of Ghent) a span of 17 m.

The Dutch portion of the canal is 16 km. long, whilst the Belgian portion is 18 km. On the latter there are 8 swing bridges with a span of 17 m.

The two reaches of the canal between Ghent and Terneuzen are separated by locks in the two branches at Sas of Ghent; the ordinary fall is 0.45 m.

Smallest section of the canal:

Depth of water	6.05 m.
Width at the bottom	17.00 "
" " " waterline.	47.00 "

Rules of Navigation.

The maximum dimensions for vessels admitted in the canal are:

Width	11.50 m.
Length	90.00 -
Draft (in the Terneuzen lock)	5.61 -

The maximum speed per minute is fixed for steamers:

With a draft of 2.75 m. and over at	145 m.
" " " not exceeding 2.75 m. at	170 "
" " " " " 2.00 " "	200 "
" " " " " 1.50 " "	250 "

The winter of 1890—91.

The maritime navigation of the port of Ghent having developed especially since 1885, when the important improvements carried out by virtue of the convention of 31st of October 1879 between the Belgian and Netherland Governments were in process of completion, we will not occupy ourselves with periods of frost anterior to that of the winter of 1890—91, when great difficulties had to be contended with in respect to navigation.

The frost during the last few days of November offered no obstacle to navigation.

After a few days thaw the pieces of ice had disappeared, when the frost began on 6th of December to last till 22nd of January, with the exception of an interval of three days (12th—14th of January).

The thickness of the ice at Sas of Ghent was:

20th December	16 centimetres.
28th „	26 „
3rd January	32 „
10th „	38 „

As the navigability of the canal from Ghent to Terneuzen depends upon the continuation of navigation on the Lower Scheld below Terneuzen, we will first examine the situation on this portion of the Scheld.

Before Terneuzen floes of ice had showed themselves in considerable quantities from the 17th of December, but until the end of the month they interfered little with navigation.

A measure, the consequences of which were much to be regretted at Ghent and Terneuzen, viz. a decree published 3rd and 4th of January, forbade the pilots of the Belgian and Netherland Governments to bring vessels up to Terneuzen, so that for four consecutive days (from 4th to 7th of January) not a single boat bound for Ghent entered the canal.

Fortunately on the 8th of January the pilot service was continued, after the steamer „Vegesack" had made the journey from Flushing to Terneuzen without a pilot and in the same time as usual.

After that the navigation of the Scheld below Terneuzen was continued, advantage being taken of the day and the tide; only towards the 18th of January was the moving ice more firmly packed than ever.

Between 14th of December and 24th of January 120 vessels entered Terneuzen and 109 put to sea from thence, but only one of them, which got among the ice from the Scheld, received any damage at her waterline, and this case was of small importance.

After 11th of December blocks of ice began to hinder navigation in the canal; the situation became worse from day to day and was with difficulty overcome without having recourse to artificial means.

Commencing on the 15th or 16th of December, two tugs were set to work. They endeavoured each day to run twice from one end of the canal to the other. They also had to come to the help of any vessel which might be stuck fast in the ice.

A third tug was stationed at the port of Ghent to lend assistance to vessels.

In going up and down the canal, the tugs endeavoured te break the ice over as great a width as possible without confining themselves to the same passage.

By this method the ice right across the canal was broken into pieces, so that vessels were able to pass each other at any point in the canal and it thus was unnecessary to confine these manœuvres to certain fixed stations.

Nevertheless the tugs were unable to continue the struggle against the ice; they were one after the other put *hors de combat;* the difficulty of replacing them became greater each day; navigation became more irregugular and towards the end of December, during the most severe frost, the tugs were obliged to give up work.

After December 29th vessels had to force their own passage through the ice.

The suspension of the pilot service on the Scheld on the 3rd and 4th of January dissipated all hope of escaping a stoppage of long duration.

On the 4th of January a few boats went down from Ghent to Terneuzen, but on the 5th not one went through the canal.

Fortunately the steamer „Ouse", bound originally for Antwerp, arrived at Terneuzen on January 1st where she awaited her orders and left for Ghent on the 6th and succeeded in reaching her new destination.

After the steamer „Ouse" had gone up another boat came down the canal; the steamer „Vegesack", arrived at Terneuzen on the 8th, made no effort to go up and it was only on the 9th January that the canal was used once more, this time by the last three boats, which were at Ghent, the steamer „Ouse" taking the lead.

The boats which arrived at Terneuzen after the recommencement of the pilot service, were now able to go up and although the journey was accomplished in some cases with more or less delay, navigation continued until the 18th of January.

On the 19th several boats bound for Ghent did not succeed in getting up, so that in consequence of the hard frost during these days the situation became very critical, for it goes without saying that the navigation, continued for more than a month, had formed flakes of ice much thicker than the original coating, and the fear seemed very well founded that the reestablishment of navigation through the frozen pack would be impossible with the means that could be disposed of.

It was the steamer „Ouse" once more which, on the 22nd of January, the day before the thaw, made a passage in the most brilliant manner.

Leaving Ghent at 7 o'clock in the morning she arrived at Terneuzen at 5 in the afternoon.

For this journey the waterline had been arranged in such a manner that the draft at the prow was very small while at the poop if was greater than the ordinary draft when fully laden.

Where the ice offered much resistance, the vessel slid slowly on to the surface, which then gave way under the weight of the boat.

If she went astern to make a spurt, her speed was kept down; the boat was not exposed to shocks calculated to damage her.

Although the engines were driven at full speed the boat often came to a stand-still, but nevertheless the ice finally bent and gave way.

The action of the vessel therefore differed from that of the tugs, for they had to split the ice and make a breach in it. They drew back at short intervals to go at it once more and exhausted the speed acquired.

The tugs and their engines could not stand these repeated shocks and although their draft was 3 m. or more, the screw was exposed to damage from the floating blocks of ice.

The following are the dimensions of the „Ouse":

Length 67.25 m., beam 9.25 m., draft when fully laden 4.15 m. She was built in 1884 by Messrs. W. Dobson and Co. of Newcastle and is said to be provided with a powerful engine.

Between the 14th of December and the 24th of January 161 vessels passed through the lock at Sas of Ghent, 81 of which were going up and 80 coming down.

Two of them had their screws broken, but they were boats of small dimensions and one of them met with this accident while going hard astern when she had approached too near a bridge.

The navigation was not stopped by these accidents.

Boats were generally able to maintain the regulation speed, which is a most important circumstance, because the movement produced in the water during the passage of vessels sailing at ordinary speed is sufficient to separate the fragments of ice that have frozen together again on each side of the channel.

Although (in the Dutch portion of the canal) the banks are not in the most favorable condition, being only here and there properly firm, the ice did not cause them any serious injury.

Briefly then it may be said that special measures with regard to navigation were not taken; special passing stations were not established and the ordinary speed was not reduced.

The only aid given to navigation was to break the ice on the canal as long as the tugs were available for this purpose.

For the rest, it was left to the vessels to open for themselves a passage through the ice.

This system which was shown to be most effective during the severe winter of 1890—91, gave equally satisfactory results in the winter of 1892—93; but the ice was then less thick and the circumstances less unfavorable.

During the latter period of cold it was sufficient for one tug to make the journey once a day between Ghent and Terneuzen.

The expenses of a tug may be estimated at 100 francs a day, excepting unforeseen repairs.

CONCLUSIONS.

The possibility of preventing ice blockades on sea-water canals cannot be doubted.

Of the means to be adopted, the creation of a channel by hand or by *blasting must be rejected as being too expensive and requiring too much time.*

The continual passing of vessels through the canal from the commencement of the frost may be considered as an efficacious means of preventing an interruption of navigation.

Ordinarily two or three passages a day will be sufficient to prevent the formation of ice, so that successive passages do not meet with insurmountable difficulties.

When trading vessels do not ensure a sufficient movement, they should be aided by ice-breaking boats of special construction or by powerful tugs, which will also be able to break through the ice on each side of the channel.

As long as the ice is not exceedingly thick the tugs will be able to lend most valuable assistance, but they will not be able to continue the struggle against the thick ice during several consecutive weeks. They then even endanger the obstruction of the navigable channel, should they be disabled by a succession of injuries to the screw, the engine or the hull.

When it is a question of opening a passage through the ice, especially for any considerable distance, an ice-breaking boat of strong build and great power which breaks the ice by its weight will be able to render the service required; or else a boat of a suitable description, made to break the ice in the same way, may be used without exposing itself to danger.

When circumstances admit of it, it is most important to break the ice over the whole width of the canal, in order to avoid the formation of solid ice on each side, through which boats cannot penetrate, and to lose no time in passing stations.

Although in a canal with broad submerged slopes it becomes necessary to reduce the speed in order to avoid the choking of the channel by large floes becoming detached from the banks, experience does not generally require a reduction of speed, either for the sake of the boats or the banks.

A suitable speed will even in many cases facilitate the separation of pieces frozen together, by reason of the movement produced in the water.

Translated by FRANCIS A. OLIVER.

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3th QUESTION.

Efforts to clear the ice on some of the Dutch rivers,

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EFFORTS TO CLEAR THE ICE ON SOME OF THE DUTCH RIVERS

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I. INTRODUCTION.

The continual growing of the interior navigation on Dutch rivers makes it necessary to follow the experiments made to clear the ice, although these efforts have not been made to facilitate the navigation but simply to prevent inundations.

II. FORMATION OF THE ICE ON RIVERS.

Relatively to the phenomenons of the formation of ice and ice banks, it is to be remarked that there is no subject on which people like so much to give their ideas upon, than on the ice in rivers.

Generally the sentences are the more decidedly outspoken when the persons have had no occasion to study the question and to make personal observations.

The quantity of ice depends naturally on the extent of the water and on the degree of cold.

During high water more ice is formed than by low water and with sharp frosts there is more and thicker ice than by light frosts.

Sometimes high water prevents the forming of ice banks while this would happen during low water and by the some degree of cold.

Ice on rivers is formed in different ways as: ground-ice, ice on the surface, snow-ice, white or hard-ice etc.

It comes to the surface of the water and floats, first as small ice flakes which increase in form and extent and finishes by covering the whole river and forming compact masses on high grounds in narrow passes and bends, at all places where obstructions stop the drifting of the ice.

On the Dutch rivers the lower parts are generally first caught; firstly where the tide has the most influence on account of the movement backwards and forwards, the flood tide pushes the ice back against the ice flowing with the ebb and causes in that way the formation of ice banks.

The ice-banks are started in the lower parts but on account of the vigorous action of the tide the mouth of the rivers remain generally open to navigation.

In the Zuiderzee, at the mouth of the Zwolsche Diep and Gelderschen Yssel, where there is only about a rise of one foot between flood and ebb the sea is caught first and then the mouths of the rivers, subsequently the upper parts of the rivers on account of the flowing ice, excepted at some places.

The Neder-Rijn, the Lek and the Nieuwe Maas get blocked from the point of the two bridges; those of the railway and the town of Rotterdam, but not below these bridges. On account of the tide action and of the steam navigation the distance between these bridges and the sea remains navigable in the channel of the stream. The Nieuwe Maas, the Lek and the Neder-Rijn, being caught at Rotterdam, keep back the ice in case of continued frost higher up the rivers untill they are completely covered.

In general the Waal freezes only when the Boven or the Nieuwe Merwede are caught. Especially the Boven-Merwede freezes sooner on account of the high grounds and the sand banks that cover the bed of the river.

The Boven Maas freezes sooner on account of its small depth and sharp bends.

The rivers situated between the Hollandsch Diep, the Lek and the Boven-Merwede, that is to say the so called navigable courses of Dordrecht, are quickly and regularly frozen, and clear slowly but orderly without provoking disasters.

The quantity of ice that flows down the rivers depends with stormy weather on the direction of the wind. The flowage of the ice on the Boven-Rijn takes place with a southerly wind, especially by the Pannerdensch Canal and during a northerly wind by the Waal.

At the branching of the rivers at Pannerden and Westervoort the direction of the wind has an influence on the floating down of the ice.

Besides the bends and shallows, the bifurcations of rivers occasion the building of ice banks.

During the winters since 1770 that have occasioned disasters and breaches in the dikes one of the branches near the main separation point, either the Pannerdensch Canal or Waal has been barred 12 times and during the same time one or another branch near de-Plei at the origin of the Yssel has also been barred 8 times.

The Boven-Rijn in Germany has been more favoured.

During hard frosts the Rhine freezes generally very quick at Loreley and at Kamereck a little above St Goar. From there to Cologne a distance of about 80 miles, the river remains often open.

Thus, the quantity of ice coming from Germany is not so considerable as one might believe.

The more rapidly and regularly a river is taken by frost so much the better for a rapid and regular clearance brought on by thaw.

III. ESSAYS OF ARTIFICIAL CLEARANCE.

The first essay was made in the year 1845.

In the neighbourhood of Ophemert on the Waal the first attempt was made to blow up an embankment of ice of two to three metres thick by gun powder.

These attempts were made on a small scale and had but middling effects.

From 1845 to 1861 nothing more was done in this country to make artificial clearances.

The dangerous ice embankments on the rivers during the winter 1860—1861 caused new attempts to be made for artificial clearance.

The 1st of February 1861 the government hired an iron steamboat of 100 horse power, 33.50 metres long, and 6.10 metres large to break the ice on the Nieuw Maas, the Lek, the Noord, the Dordtsche Kil, the Merwede and the Waal.

The thickest pure ice was about $^3/_4$ foot.

Some parts of the river were encumbered to the bottom. For instance near IJsselmonde on the Nieuwe Maas on a distance of 300 metres.

That embankment broken, the steamer went up a part of the Lek and the Noord as far as Papendrecht; then it turned in the Hellevoetsluis, and continued to Hardingsveld passing the Hollandsch Diep and Kil.

On the way the steamboat did not meet any further embankments; but places covered by hard ice more or less thick and also floating ice.

After this she went to Loevestein, were at the mouth of the Waal heaps of ice had formed along the sides; that ice was composed of bands of hard ice, between which existed soft ice, that filled the river to the bottom.

With the aid of the pression of the water kept back by that embankment of a length of 1600 metres, the clearance took place in three days.

After this the boat having worked 9 days was sent back, the ice floating down well.

The steamboat had not much suffered, only a little at the wheels and rudder, imputed to the soft melted ice.

In 1871 different attempts were made.

The Nieuwe Merwede was entirely encumbered by very thick ice that covered the river for a length of 4000 mètres above the Hollandsch Diep. The ice was cut in, broken by steamboats, and blowed up by powder. In this way the clearance was made before the thaw.

Two boats were used to break the ice and 101 mines were sprung with a use of 3038 kilos of powder.

This work was done under very favourable circumstances, as in the neighbourhood the railway bridge over the Hollandsch Diep was being built and the implements, tools, machines etc. serving for that construction were used for this object.

During this work, from the 3 to the 10th of February a heavy frost set in and this prooved that the means used had but little effect, the ice being very hard, and the openings made by the blasting were immediately filled by floating ice and became again a compact mass.

In 1876 other attempts were made from the 2 to the 8th of February by a steamboat on the Lek.

The low water hindered this operation very much.

The next artificial clearance took place during the winter of 1879—1880.

The first time, from the first to the 19th of January on the Nieuwe Merwede, the Boven Maas near Woudrichem and on the Dordtsche Kil; 1140 Kos. of powder was used to the effect, also two boats of 100 and the other of 93 horse-power and a respective draught of 2.07 and 2.10 metres.

The second time, one of these boats was employed during three days to clear the Lek and to break open a sort of embankment on the Boven Merwede, near Hardingsveld.

Two monitor rammer steamboats of the Royal Marine were also used for the clearance of the Dordtsche Kil and the Nieuwe Merwede; it was prooved by this experiment that such boats are not fit for such work. They steer badly, are too heavy, have insufficient moving power and are too difficult to move about on rivers.

During the winter 1880—1881 for the clearance on the rivers Nieuwe Merwede, Boven-Maas, Dordtsche Kil, Nieuwe Maas and the Lek, two tugs were used covered by a breast-plate, and two monitor rammer steamboats were again put into action; meanwhile mines were also sprung. The two monitor boats gave as little satisfaction as before.

After the winter 1880—1881, the idea was brought forward again of building a vessel specially for the clearing of ice and for which the government would give a subsidy; it was adopted in 1883.

A contract was made with a shipbuilder who was at the same time an undertaker of towage, by which he put at the disposal of the government a steamtug specially constructed for the breaking of ice but if not occupied at this work the owner would have the exclusive use of it.

An annual retribution of Fl. 9200 during fifteen years was agreed upon.

To this end the iron paddle strongly built steamboat called „Wodan" was constructed: she measured 40 metres in length and was 13.40 metres large, the width of the paddleboxes included. The draught of this boat is of 2 metres and she has two engines of 50 horse power each.

The two engines are of double expansion (system Wolf compound) and the two paddles are independent of one another in order that these can turn separately backwards or forwards. Herewith is a sketch of the tug. The drawing represents also the spur which was made afterwards and which will be explained later on. This vessel has been used for the first time to clear ice in January 1885; also two other steamboats not specially constructed and only rented for this purpose.

The Wodan gave that year satisfactory results but it must not be forgotten that the winter frosts were not heavy and lasted but a short time; therefore the ice on the rivers was not thick and not to be compared to the quantity and hardness of the preceeding years.

After the lastly spoken of clearances in January 1885, other attempts were made by steamboats and by blasting during the years 1890—1891 and 1891—1892 and in the last winter. For the last clearance no mines were sprung on account of the small quantity and the little thickness of the ice.

IV. DETAILS OF THE CLEARANCES MADE BY THE ICE-BREAKERS DURING THE WINTERS 1890—1891 AND 1892—1893.

Hereafter will follow ample details concerning the attempts of the ice-clearances made in the winter of the year 1890—1891, during which heavy frosts set in even more than during any of the preceeding winters during which essays of artificial clearance were attempted. Also those relatively to the winter 1892—1893.

For the description of the state of the ice and detailed daily reports concerning the works of clearance please to read the printed reports of what has happened on the Dutch rivers during the winters 1890—1891 and 1892—1893 at the office of the section of the present congress.

A. The Winter 1890—1891.

1. The means to facilitate the clearance.

According to the preceeding attempts it was shown that it was impossible to begin the clearance before a continued thaw set in and that steamboats were unable to stop icefloes from freezing into a compact mass.

Besides the Wodan transformed into an ice-breaker a contract was made, as it had been done in preceeding years, to hire 8 tugs which had been strengthened round the bow. The Chief Engineer entrusted with the management of the rivers who had the direction of the clearance, had regulated all the works with the lieutenant-colonel, commanding the corps of Royal Engineers and the major commanding the corps of the torpedo-boats.

The dimensions of the 9 steamboats were as follows:

		LENGTH.	WIDTH.		DRAUGHT.	HORSEPOWER.
Wodan,	paddle steamer.	40.00 m.	13.40 m.	paddle boxes included.	2.00 m.	100
Maassluis	id.	34.10 »	11.90 » main-frame 6 m.		2.10 »	93
Zeeland	id.	33.50 »	12.00 »		1,65 »	80
Rotterdam	screw steamer.	30.00 »	5 »	midships.	2.80 »	60
Generaal v. d. Heyden	id.	31.40 »	6.30 »		2.10 »	60
Colonel	id.	23.30 »	4.90 »		2.25 »	30
Dieudonné	id.	27.43 »	5.94 »		1.73 »	60
Hosanna	id.	28.00 »	5.60 »		2.00 »	45
Hoek van Holland	id.	20.82 »	5.36 »		2.25 »	30

With the aid of the detachments of the corps of Engineers and the torpedo corps the first thing to be done was to facilitate the action of the steamboats, by blasting at the places were the action of the clearances could not harm the lower districts and where the boats could not reach.

At different places on the river 21 boat-sledges had been prepared with necessary implements, such as axes, lanterns etc., etc. To break the ice on the rivers Hollandsch Diep. Merwede, Waal, Maas and the navigable courses of Dordrecht the following steamboats were used: Wodan, Zeeland, Rotterdam, Generaal van der Heyden, Hosanna, Hoek van Holland, while the other boats: Maassluis, Colonel and Dieudonné would work on the Nieuwe Maas and the Lek.

Also for the first named rivers 3 detachments of the corps of Engineers and for the last named 1 detachment of the torpedo troups were designed to spring the ice by explosives in front of the steamboats and to break the embankments of ice.

Other detachments of the corps of Engineers were engaged for the clearance of the Rhine, near the German frontiers and the Yssel.

2. CONSIDERATION ON THE RESULT OF THE MEANS EMPLOYED.

Although with the means disposed of everything would be done to attain the end proposed, that is to clear the mouths of the rivers, the work that had to be undertaken was so important by the extraordinary frost, that one could foresee the insignificant result in taking in consideration the preceeding experiments made.

If for instance the ice had been less thick, as it was in January 1885 when a steamer (like the Wodan) had been enable to break an embankment of 8 kilometres long on the Dordtsche Kil in about $4^1/_2$ hours, in this case it was quite impossible as the ice was too thick.

It was only possible to make an opening by striking against the ice at full speed and making sudden spurts of 150 mètres; even after a continual thaw of 15 days the white ice was still so strong that the Wodan taking a run of 150 mètres at full speed and striking the ice penetrated in the mass only about the length of the boat and having great difficulty to get away again to make another run.

The other steamboats being less powerful did naturally less work. It is useless to say that little progress was made and that the implements and engines suffered very much from the beginning to the end of the ice-clearance.

The effect of the springing of the mines did not facilitate the working of the boats so much as it had been hoped, although the corps of Engineers fulfilled their task with the most infatigable perseverance and with great prudence.

In average the openings made with all the disponible forces on the Hollandsch Diep and Nieuwe Merwede were of about 500 to 600 metres daily on a width of about 250 metres.

The whole length from the mouth of the Nieuwe Merwede down to the railway bridge on the Hollandsch Diep is about 21000 metres, thus the result is middling in taking into consideration the end proposed.

More boats to break the ice would have been useless as each boat when trying to make an opening wanted the necessary space for maneuvering and it would have been impossible that more steamboats could work side by side in the course of the stream.

Better results were obtained on the Nieuwe Maas and the Lek as the crust of ice was less thick and there were smaller ice-banks. The clearance made was of a daily average of about $1^1/_2$ kilomètre on the whole width of the river.

3. DAMAGE SUFFERED BY THE STEAM BOATS.

After the clearance when the steamboats were in dock it appeared that they had generally greatly suffered. The prows of nearly all the boats had their plates more or less driven in and partly cracked and every one of them made water. Also all the screw steamers had one or several screws broken and their shaft damaged. The paddle boats had damage to their paddles, centre pieces broken, fellies or iron rays broken or bent and other implements damaged.

All the boats had damage to their rudders.

The engines were in rather good state, no important damage in that way.

4. COSTS.

The total sum of costs for hire, works and repairs caused by this clearance amounted to fl. 72404.54.

In adding the sum paid during five years to the owner of the steamboat Wodan, transformed in ice-breaker, forms the total of fl. 118.404.54.

For that amount the clearance of last winter took about 800 hours, the cost is fl. 148 per hour.

If the subsidy for the construction of the Wodan is not counted the cost is fl. 79 per hour.

The following table gives the details of the expenses made.

Name of the boats.	Hire and service.	Cost of repairs.	Total expenses.	Working hours.	Hours of inaction.	Cost per hour.	*REMARKS.*
Wodan . . .	*fl.* 14332.50 *a*)	*fl.* 3537.55	*fl.* 17870.05 *a*)	129½	268½	*fl.* 66.95 *b*)	*a*) In this sum fl. 9200.— are comprised 8 p.c. on the cost of construction fl. 115000.— . Added to this fl. 46000.— must be counted for the winters 1885/86 – 1889/90 the sum having been paid although the boat remained in inactivity. *b*) The annual subsidy of fl. 9200.— for the cost of the building of the Wodan not comprised *c*) That boat had serious damage in the beginning of the work. *d*) In this amount is the cost of refloating fl. 3000.— this boat having sunk 14 m. deep and fl. 12283.45 for repairs to the boat costs of arbitrage comprised *e*) This boat sunk quite in the beginning of the works.
Maassluis . .	4800.—	3886.45	8686.45	125	233	69.49	
Zeeland. . . .	1661.25	6683.90	8345.15	23½	211¼	335.11 c)	
Rotterdam . .	3305.—	3840.—	7145.—	118	204½	60.55	
Generaal van der Heyden.	1502.50	16787.45 *d*)	18289 95 *d*)	45½	156½	401.97 *e*)	
Colonel	2435.50	1266.50	3702.—	161¾	219¾	22.88	
Dieudonné . .	1713.—	1360.24	3073.24	97	157	31.68	
Hosanna . . .	1457.50	1733.—	3190.50	40½	163½	78.78	
Hoek van Holland . . .	1045.—	1057.20	2102.20	59	116	35.63	
Total . . .	*fl.* 32252.25	*fl.* 40152.29	*fl.* 72404.54 and *fl.* 46000.— for the „Wodan" 1885—1890.	799¾		*fl.* 148.—	

The winter of the year 1892-1893.

The insignificant results of the artificial clearance during the winter 1890-1891 and the high costs occasioned especially by the use of steamboats caused other means to be studied to arrive at a better result and with less costs. The proof had been made that although the steamboat „Wodan" was strongly built it could not stand the continual shocks against a hard, transparent and compact ice of 25 to 45 centimetres thick.

The other steamboats were yet more unable, on account of their build, to resist; the break downs that took place at every moment, also the damage to the paddles and screws, caused not only much cost but also great loss of time.

As a trial it was decided to give to the Wodan a spur or plough according to the sketch on the plan I herewith.

This plough made of soft steel was constructed in such a way that it should float by itself in the position as required, which was desirable on account of the great weight of this instrument.

The plough was fixed in the front of the Wodan with the bottom part covered by about 60 centimetres water. The proposed plan was to push the plough under the ice and breaking it from underneath and not to run against the ice to make splits as before.

It was easy to comprehend that in this way the steamboat would be less damaged. A few shipowners had also provided some steamboats with ploughs at their cost. The tug „Pernis" had also a plough formed in the same manner as the one of the „Wodan". Two other boats, the Freya and Jason had also ploughs on the same principle but different in form. On the sketch herewith will be found the drawings of the Freya and Jason with their ploughs; these boats had also screws of soft steel.

The clearance of certain rivers having been thought necessary during the winter 1892-1893 the boats Wodan, Pernis, Freya and Jason equiped in that way were sent to clear the Hollandsch Diep, the two Merwedes and the Waal.

With the other boats the Hosanna was also employed, but without plough, principally to be used as a transport boat for the miners who would aid the efforts of the other boats by explosions.

But still it must be noted that the rivers were much less encumbered by ice during this winter than the preceeding one. The frost that had set in on the 21st December 1892 kept on variably untill the 13th January 1893. All the rivers were closed by a crust of ice of about 25 centimetres thick, and with heaps of ice that reached often the bottom of the river and representing a thickness varying from 70 centimetres to 3 metres. The Nieuwe Merwede and the other lower rivers made exceptions and there was hard floating ice covering the two thirds of the surface of 4 to 13 centimeters thick.

Contrary to the principle adopted formerly of beginning the breaking of the ice when the thaw set in, it was decided to attempt before the thaw to hinder the Nieuwe Merwede to close up. This river was encumbered by large masses heaped up against the banks nearly closing up the lower mouth which can be considered as the principal way of discharge for the water and ice higher up.

According to the proposed plan the ice-breakers went through the Hollandsch Diep to the Nieuwe Merwede and as long as the ice lasted it was decided to try to stop this last river from closing.

Two boats were employed to break down the heaps of ice filling the greatest part of the mouth of this river, while the other two would run continually from one end of the river to the other to prevent the pieces of ice to form a compact mass. If the thaw set in it was decided to clear the ice higher up after having broken the barriers in the mouth of the Nieuwe Merwede.

The miners would help the work of the boats and operate especially in the places where the vessels could not reach.

If the results of the year 1890-1891 were insignificant as it has been described, the works that we are now speaking of were more favourably done on account of better circumstances and better implements so that when the natural clearance of the ice commenced the ice in the Nieuwe Merwede was floating and also on a considerable length of the Boven-Merwede and the most essential thing was that all the heaps of ice in the shallow parts were all broken down.

As to the effects produceed by the steamboats with ploughs it was ascertained since the beginning of the work that neither the Wodan nor the screw boats could advance regularly even where an even field of ice had been formed when the ice was 25 centimetres thick.

Useless to say that it was yet more difficult to advance in places were heaps of ice had been formed. Although the Wodan took runs at full speed against the edge of the icefield she penetrated generally about half her length in the mass, sometimes her whole length but rarely further.

The screwboats armed with sharper ploughs (Freya and Jason) penetrated generally easier in the fixed ice.

It is without doubt that better results have been obtained with steamboats provided with ploughs than without.

Thus during the winter 1890—1891 9 steamboats without ploughs were used. These were put at the disposal of the government during $2529\,^3/_4$ hours and they worked at the breaking of the ice during $799\,^3/_4$ hours, while the 5 steamboats which were used last winter, 4 of which had ice ploughs, worked 775 hours in the ice during a total service of 1945 hours.

This favourable result is due not only to the steel screws but also greatly to the ploughs protecting the prows. In consequence continual leaks did not happen as during the preceeding winter and interruptions in the work to repair damage. In this sense the ploughs used by the Wodan and Pernis are preferable to those of the Jason and Freya, the first protecting the prows much more. But the model of the Jason and Freya being much sharper succeed better to cut the masses of ice than the other shape. It is true that on a field where the ice was not heaped up, the paddles of the Wodan had effect over a wider space and sometimes large pieces of ice were loosed and drifted away, but the flat plough on the contrary had less effect on heaps of ice of two metres or more and still it is exactly in those parts that these ice breaking implements should produce an effect.

The boat could sometimes hardly get loose when it was at work at these embankments. Often another steamboat had to help to break the ice to enable her to be cleared. The effect produced in these heaps was less than by the Freya and Jason which having sharper ploughs loosened themselves nearly always alone.

The steamboat Hosanna without plough had after two days work such a dangerous leak that the was unable to continue and had to be repaired.

If the use of ploughs can be judged as favorable for quick work it is to be remarked that the boats employed to break ice should be much stronger built than tugs generally are. The prows of the boats protected by the ploughs against leaks have another and serious inconvenient.

The example of the Freya proved this evidently. This boat having been used during one year for artificial clearance and although its build is much stronger than of ordinary tugs it was ascertained by the inspection in dock that the whole boat was disjointed. This was also the case with the Jason although this vessel had been less used.

The Wodan resisted much better on account of its special strong build.

The number of screws broken was less if compared to preceeding years.

The cast iron screw of the Pernis broke twice and the screws of the other boats were so little damaged that it was found unnecessary to replace them. This is to be ascribed to the use of steel screws.

As the boats with ploughs could continue their work during a longer space of time than in preceeding years the engines had also more to endure. Tho Wodan had especially much damage done to its engines.

In general the paddles of this boat were in good condition but the rudder received an important injury by its being caught in floating ice.

The costs of the use of these steamboats were as follows:

NAME OF THE BOATS.		Hire and service.	Cost of repairs.	Total expenses.	Working hours.	Hours of inaction.	Cost per hour.	REMARKS.
Wodan		fl. 18145.—(1)	fl. 7611.34	fl. 25756.34	195	303	fl. 93.05 (2)	(1) The sum fl. 9200.— for the annual hire of the boat according to the contract of the 30th March 1883 and fl. 2000.— for one years hire of the plough according to the contract of April 1892.
Freya	with	5170.—	13603.18	18773.18	196	287	95.77	
Pernis	ploughs	2305.—	1594.35	3899.35	89	153	43.81	
Jason		2740.—	3296.40	6036.40	114	126	52.95	(2) The hire of boat and plough comprised.
Hosanna		3365.—	3172.32	6537.32	181	301	36.11	
Total . . .		fl. 31725.—	fl. 29277.59	fl. 61002.59	775	1170	fl. 78.71	

C. Ice breakers of the Elbe class.

Although the results obtained by steamboats with ploughs are more favourable than those without this implement the costs of repairs resulting of the weak build of the boats are too high compared to the results.

It was therefore necessary to find boats more strongly built. This idea induced the government to examine if it would not be possible to use the same ice breakers on Dutch rivers as those used on the Elbe above Hambourg with favourable results.

During the discussion of the budget of the State for 1894 the necessary sums were voted to build an ice-breaker, as trial, on the model of the one used on the Elbe. It is being made and will cost fl. 47000.— The sketch of the boat will be found herewith. Here are other details.

The vessel measures 28 metres in length on the water line; 6 metres width and 1.60 m. to 2 metres draught.

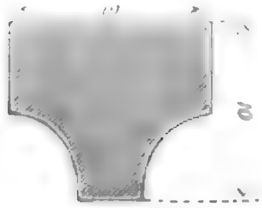
The hold is flat at the bottom; the keel from the poop to the middle of the vessel, follows a straight line with a rise of 30 centimetres and curves in a parabola to the prow. At 60 centimetres from the prow, the tangent of that curved line makes an angle of 17 degrees with the water line.

Forward the keel emerges and makes a round insensibly to the prow.

The build of the back of the boat is such that during the clearance of the ice the pieces loosened keep clear of the screw.

In free water the boat runs at a rate minimum of 5 metres per second.

In the middle of the hold a steel keel of 10 centimetres high, in the form of the annexed drawing, has been riveted to the outside of the vessel to concentrate the pression when the boat goes through an ice field and also to hinder the boat to drift off when in movement.



To strengthen the outer skin a combination of transversal and longitudinal frames has been imagined and stiffened by five watertight partitions.

The dimensions of the stem are 120 × 40 millimetres, and those of the sternpost 120 × 5 millimetres.

In the front part of the vessel the frames are distanced 30 centimetres, in the middle 35 to 40 and the further end 50 centimetres apart.

To render the build still stronger longitudinal frames have been disposed on the keelsons and at the height of the water line.

The thickness of the iron plates is 10 millimetres in the front part of the vessel to the water line and 13 millimetres below it; in the middle and at the back 9 millimetres and at the other parts not exposed 8 millimetres.

With exception of the forged pieces the vessel is built in steel.

In front and at the back of the vessel spaces have been left open to be filled with water to serve as ballast. This water is pumped in by steam power and can be taken out in the same manner. To stop the water from freezing it can be warmed by steam.

The engine is vertical, high and low pressure and condensation at the surface or by injection; it can serve also without condensation; it is fixed in an exceptional strong manner and of 250 horsepower.

The boiler is of the tube system.

The screw is in cast steel with four blades; its diameter is 160 centimetres. The shaft has 15 centimetres diameter. An electric search light has been installed on the prow.

With such ice breakers the results on the Elbe have been very satisfactory during the last winters especially for freedom of damage to these boats. They operate in sliding on the ice fields that they break by their heavy weight. That way is quite different to the one used in Holland. That is why the keel has a special form.

It is not necessary to point out that these run much less risk of injury than the boats that run against the sides of the ice field to break the ice or the ploughs with submerged spurs breaking the ice in lifting. The different sketches found herewith explain the different methods of working.

The advantages of the icebreakers that slide on the ice to break it, that have been used on the Elbe are not only due to the model of the boat but also to the fact that the ice banks on the Elbe are in general much less than in the Dutch rivers.

That can be explained as follows:

Firstly the speed of the current on that part of the Elbe above Hamburg is small compared to the Dutch rivers; therefore the ice being less pushed does not heap up. Also the Elbe is in that part much more regular than the lower parts of our rivers.

Although there exists still a great number of sand banks in the Elbe these remain generally much deeper under water. Even during the ebb these sandbanks are rarely to be seen.

Generally the ice banks form themselves during the ebb on banks that are then visible and remain heaped up especially in the lower parts of our large rivers where the works to regulate our rivers are not quite finished yet. It is also without doubt that the many bifurcations of our rivers have also a bad influence; the consequences are stagnant waters at the points where the branches separate, and the ice heaps up in those parts and forms embankments. The current divides itself much less in the lower part of the Elbe. That river has also the advantage of having its mouth in a north westerly direction and is therefore more favourably situated for the winds existing generally during thaws, than our estuaries of Goeree and Brouwershaven where the ice has principally to be discharged.

For these reasons the heaps of ice will create more serious inconvenience on our rivers than on the Elbe.

Although the boats of the Elbe class offer great advantages as to repairs and progress in working, even these will be nearly useless on embankments of ice like those that form themselves on our rivers of sometimes 1000 metres long and occupying the whole width of the river to the bottom.

The boat sliding at all speed against the surface of such heaps will remain standing or else slide back again.

In these conditions the work of clearance must be abandoned in great part to the miners.

Still if one would try to use these boats, even in these particular circumstances, they should be provided with ploughs like those used by the Jason and the Freya during the winter 1892—1893 which could be done easily.

These last named steamboats have worked with success in 1893 in breaking down embankments and heaps of ice.

V. ARTIFICIAL CLEARANCE OF RIVERS BY MINES.

A. Cases when explosives were used.

In the attempts that have been made to cause artificial clearances explosives have been often used. Although these have not been made on such a large scale that a full judgement can be formed on their efficacity, the experience acquired in different circumstances during the last winters is important enough to review the results and at the same time to discuss the subject.

In the III chapter a view of the cases has been given where one had recourse to artificial clearance by explosives.

Up to 1891 explosives were used to blast the ice only above the point where the ice-breakers were working. During the winters 1890—1891 and 1892—1893 explosives were employed on a large scale; they were used to help the boats in clearing the ice in the middle of the stream of the rivers downwards, or else to clear the heaps of ice with or without the help of the steamboats. It is especially the results obtained in January and February 1891 and 1893 that must be spoken of here; the reports of the engineers and commanding officers of the detachments, also the experience of the author of this paper are the sources for the information given in this chapter.

Those who interest themselves in the question will find in the reports of what has taken place during the winters 1890—1891 and 1892—1893 on the dutch rivers all details on the state of the ice, of the clearances etc. and the maps of the same years will also help to explain the question discussed here.

The circumstances when explosives are used were the following.

a. To help the ice-breakers in the clearing of the embankments (embankment is the ice that closes wholly or partially the rivers with ice-floes caught underneath).

b. To clear altogether the barriers formed of heaps of ice.

c. To maintain with the aid of the ice-breakers the continual floating down of the ice during the frost and help the clearings where the water being too low the ice-breakers could not reach.

For the cases *a.* and *b.* it has been found necessary to commence the work when a continued thaw sets in because during the frost the embankments and barriers broken or split form immediately again a compact mass, and it would therefore be useless work, excepting when ice can float downwards to the sea.

a. The breaking of embankments.

In 1891 and 1893 the aid of the troops of engineers and torpedos was found necessary when the ice was 20 to 25 centimetres thick, the ice-breakers being unable to advance. The circumstances and manner of working have been described in the preceeding chapters therefore we will simply add that the openings made were in the direction of the run of the stream. To enable the floating ice from above to clear itself it is necessary that the openings made be sufficiently large. These were according to circumstances from 150 to 200 metres. The distances of the mines of the same furrow or the distance of the furrows varied according to the local circumstances as will be shown in the following examples.

I. Clearings of the Hollandsch Diep and the mouth of the Nieuwe Merwede during the winter 1890/1891.

From the 1st to the 5th of February 1891 a detachment of one officer and twenty men, and afterwards two detachments of 2 officers and 38 men, helped the ice-breakers with mines in the clearing of the southerly channel of the Hollandsch Diep and the mouth of the Nieuwe Merwede. Three of these boats were at work at the said places. The ice had an average thickness of 36 centimetres. At the mouth of the Nieuwe Merwede the thickness increased from 50 centimetres to 2 metres on account of the floating ice that glided underneath the sheet of ice and formed an embankment.

Number of mines sprung (powder and dynamite):

the 1st. of february . . .	21	charges.
„ 2nd. „ . . .	7	„
„ 3rd. „ . . .	15	„
„ 4th. „ . . .	11	„
„ 5th. „ . . .	19	„

The powder used varied from 10 to 25 kilos per charge the dynamite from $2^{1}/_{2}$ to 10 kilos.

The mines of powder were made under the surface of the ice at a depth of 1.75 m. to 2½ metres and the mines of dynamite at 1.50 m.

The mines made openings of 5 to 14 metres diameter, according to the ice or the kind of explosive matter used; the fissures occasioned by these explosions were generally insignificant, especially when the ice was very thick. The ordinary fissures were from 10 to 30 metres. For an exact notion of these please see the explanations in part II annexed.

The mines were disposed in a furrow 30 metres apart but if the effect produced was insufficient to help the boats used as ice breakers the mines were placed at 25 metres one from another, the furrows were spaced at a distance of 100 metres.

In five days work the course of navigation was open on a distance of about 2000 metres and a width of about 250 metres. The cause of so little success must be attributed to the great thickness of the ice, principally on account of the difficulties that the boats encountered by the damage received and also the unfavourable circumstances under which the detachments had to work. The conveyance of the explosive matters to the sand bank of Anna Jacomina by the narrow dikes was effectuated with difficulty and on account of the tide and foggy weather it was very difficult to work the mines.

2. Clearing of the Boven Merwede, the Waal during the winter 1892—1893.

There was occasion of working on a much larger scale for the clearing of the Boven Merwede and the Waal during the winter 1892—1893 than in former years or when clearing the Lek in 1890—1891. As it had been possible to keep the Nieuwe Merwede open during the frost and as a detachment of Engineers composed of one officer and twenty men had been ordered in time to Werkendam the work could be commenced at the beginning of the thaw.

Four boats with ploughs (Wodan, Pernis, Freya and the Jason) had been commissioned for the clearing with the Hosanna who had no plough.

From the 15th to the 21st of January 1893, it freezing still, the Freya and the Hosanna succeeded with the aid of the troops of Engineers in breaking an ice embankment (which was partially a barrier) at the mouth of the Nieuwe Merwede (see letter *c* of this chapter).

The thaw commenced on the 22nd of January and the Wodan having arrived, a passage of 100 to 150 metres was opened in the Boven Merwede but on account of the small depth of the water it was impossible to break the ice over a greater width.

The 23rd of January the blasting operations were commenced. The solid ice had generally a thickness of 20 to 25 centimetres, sometimes 30 centimetres. Between the Km. stones CII and XCVIII (1) embankments of ice were found varying from 0.7 to 6.0 metres in thickness, formed by floating ice that had gathered underneath the crust of ice.

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(1) The engineers of the Waterstaat have divided the rivers in Holland in subdivisions, called kilometre furrows, we have used the term kilometre stone.

Mines of powder and dynamite made openings in the furrows which according to the thickness of the ice were spaced 25 to 75 metres apart, and in each furrow 2 to 3 blasts were made (sometimes 4 to 7). In places where the boats could work alone no mines were sprung.

The total numbers of these were:

Date.		Powder	Dynamite.	Total.
23rd	January	14	7	21
24th	id.	18	27	45
25th	id.	24	27	51
26th	id.	25	34	59
27th	id.	19	7	26
28th	id.	36	—	36

The weight of the charges used was for powder 12.1 to 25 Kilos, for dynamite 2.5, sometimes 5 to 7$^1/_2$ or 10 kilos. The mines of powder were placed as well as could be, at a depth of 2 metres for 12.1 Kilos and 2.5 metres for 25 Kilos; the dynamite at 1 metre under the surface of the ice. (See annex IV.) According to the thickness of the ice, the mines of 12.1 Kilos of powder and 2.5 Kilos of dynamite made breaches of 4 to 10 metres diameter (in ice of 70 centimetres thick 7 to 8 metres diameter); the mines of 25 Kilos of powder made generally breaches of 11 to 15 metres and those of 5 to 10 kilos of dynamite, much used for barriers of thick ice, gave the same results as the mines of 2.5 kilos of powder in thin ice. The length of the fissures was generally of 20 to 40 metres; only once of 50 to 60 metres and often only of 10 to 15 metres.

The length of the course of water opened by eight days work of the ice-breakers was 14 kilometres, that is an average of 1$^3/_4$ kilometres per day.

On the 29th of January blasting was discontinued, as the ice-breakers did not arrive being employed elsewhere to break the embankments.

The 2nd of February the natural clearing of the Beneden Waal began and the 3rd of that month the water carrying the ice away very well, it was found unnecessary to continue the artificial clearing of the Waal.

The 1. 2. and 3rd of February the detachment of the Engineer troops worked to clear the Boven Merwede of barriers of ice that had been formed.

The result of the work on the Boven Merwede and the Waal can be considered as rather important and will be more detailed in this chapter letter *c*.

b. Clearance and the reducing of embankments.

During the periods of frost and thaw of the winters 1890—1891 and 1892—1893, embankments were formed on different points of our rivers.

The greatest were those of the winter 1890—1891 on the Boven Rijn, near Lobith and Millingen, on the Waal between Rossum and Loevestein, on all points of the Nieuwe Merwede, on the Yssel near Zalk and on the Maas near Grave. During the winter 1892—1893 others were formed in the entrance of the Pannerdensch Canal and the Boven Rijn near Lobith; on the Lek between Hagesteijn and Vianen; on the Waal near Well, at Afferden, Gasselt, near Beek and Oyen; and also on the Yssel near Katerveer and Zalk.

On account of the favourable circumstances in which the clearance took place no dangerous ruptures of dikes happened. The upper sheets of ice having weakened by the thaw, the masses of ice cleared away carried by strong waters the current of which was much increased by the barriers of ice. In general the clearing was aided as much as possible by the explosion of mines.

It was only in the lower parts of the rivers (for instance Nieuwe Merwede, Waal, from Herwynen to Loevestein) that the ice-breakers had occasion to work, as soon as lower down the course of the river was open.

At places where the rivers were still closed the detachments of miners had to work unassisted not only to reduce but also to clear away the embankments.

Some of the cases were mines were sprung we will describe hereafter.

1°. The embankment of the Yssel, near Zalk during the winter 1890—1891.

We take the following notes from the reports made on this subject.

The 14th of December an embankment had formed itself to the bottom of the river at the bend at Zalk, near k.m. stone CVIII, near the ferry of Zalk, on a length of 800 metres. As this embankment could become during the thaw a great obstacle for the passing of the water and ice, the boats being in the impossibility of approaching it, it was decided that an attempt would be made to break this embankment by mines, although that after the said date it diminished so much that no irregular flow produced itself between Katerveer and Kampen. On the 26th of January it measured 228 metres above and 252 metres beneath k.m. stone CVI in length and was on an average 112 metres wide; the thickness of the ice was at that moment from 45 centimetres to 3 metres; the upper ice had about 45 centimetres thickness under which other ice had crept. On that day a detachment of Engineer troops of one officer and twenty men arrived to commence the clearing. But on account of the river being closed up beneath and by the small depth of water there could not be question of a regular clearing, therefore it was decided to attempt to reduce the mass by exploding mines and make fissures in order to help the natural clearing. On the 27th of January five powerful mines of

50 kilos were blasted, but the next day it was found that the fissures were not more important than those produced by smaller explosions therefore charges of 18 and 9 kilos were used at 2.5 to 2.9 metres beneath the ice.

On account of the great surface of the embankment it was decided to commence and make holes on the deepest part of the river, that is on about half of the width of the river. After this if sufficient time was left the same thing would be done for the smaller depth.

The mines were made in oblique rows, spaced about 25 metres, the distance of the charges being 15 m.

The first time the charges were all lighted at once (in bottles) obliquely by a chain combination. Later on when barrels were used the explosions did not succeed regularly, therefore the charges were lighted separately or two by two by a modified system of connection. (See diagram 8 en 9 sketch II).

The number of explosions were:

27th.	January	5.
28	„	14,
29	„	21,
30	„	20,
31	„	31.

Thus the task for the deepest part of the river was performed. The 1th of February the ice having become brittle by thaw it was impossible to work on the other part.

The long fissures produced during the last two days made the explosions not so necessary therefore it was decided to finish work and to await consequences.

On the 1st and 2nd of February nothing modified although there was a higher pressure of water.

At eleven o'clock p. m. on the 2nd of February the ice pushed by increase of water began to move, the openings filled and a part of the embankment went down the river about 700 metres and filled a lower section. The ice up stream of the embankment did not move.

The 3rd of February at eleven o'clock a. m the mass was taken away by the current as far as Harsenhorst where it stopped again. During the night the ice field downstream floated down to Kampen.

On the 6th of February the detachment of miners returned to its quarters.

Therefore 4 days work of 7 to 8 hours were wanted to break an embankment of 70 000 square metres. It is most certain that the openings and fissures provoked by the explosions were favourable to the clearing, although the whole mass flowed down without it being followed by the ice above.

It is impossible to say if the result obtained is proportioned to the expense or if anything would have happened in case nothing would have been done.

2. The ice embankments in the Waal between Rossum and Loevestein during the winter of the years 1890—1891.

During the night of the 23rd of December 1890, the Boven Merwede having frozen over all its length and width, the upper ice closed from that day to the 31st of the same month the whole river Waal.

There was hardly no change during the whole period of frost that ensued.

Thaw having set in the 24th of January 1894 the Waal cleared on the 29th; but though the ice cleared in the upper parts different embankments (1) were formed between Rossum and the Boven Merwede. On the 20th of January at Rossum and Herwijnen the water rose to 40 centimetres under the lowest tops of the dikes and for fear of rupture different sections of the dikes were heightened. For that reason a detachment of the troops of engineers was sent which worked from the 4th to the 8th of February to reduce the ice embankments untill these cleared on the 9th.

Lower down at the height of the ferry near Loevestein, opposite Herwijnen and near Vuren the barriers of ice were less to be feared as they did not make the water rise and were also less important. But still the 7. 8 h and 9th of February they hindered greatly the clearing of the ice floating down the Waal which took its direction towards the lower rivers already cleared (Boven and Nieuwe Merwede).

We think it necessary to describe more amply the character of these ice-banks as in different rivers (among other the Nieuwe Merwede and Lek in 1892) similar embankments were formed on account of local irregularities in their beds and as the chances of clearing these ice-banks by well conducted blasting operations are very promising.

In general there exists some way below the ice-bank a field of polished and hard ice which can be passed safely, higher up the ice is cracked and raised but still will bear a man. It is there especially that during the thaw ice tries to make a passage and finding the obstacle of the bottom of the river in the end encumbers the whole bed and forms an embankment. Above the ice embankment the surface of the stream is covered by small and large floes moving through and over each other and can't be crossed even in an ice-boat than with great trouble and danger. The discharge of water being partly stopped by the ice-bank, the level of the water is raised and the river tries to leave its bed.

In examining these embankments the parts offering the greatest resistance are easily seen on account of their form and colour. The artificial clearing is done the most easily in the following manner. With the aid of strong charges of powder or dynamite placed by preference in the current it is tried to break the hard and polished ice in front of the embankment. Sometimes when the boats used as ice breakers can be employed they can render good service. In this way the embankment loses a great part of its support and disjoints itself by the movement of the water. In making the most resisting parts disjoint by heavy charges, dynamite in preference, the whole mass sets itself sooner or later in movement and is cleared by the current.

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(1) The ice from the rupture of the ice embankment near Lobith in floating down on the 1st of February through the Waal increased considerably the heaps of ice in the lower parts of the river.

To clear the Beneden Waal, two detachments were sent off on the 6th of February 1891, occupied at that moment at the clearing of the Nieuwe Merwede; the two detachments were composed of 1 officer and twenty men each. Meanwhile one of the detachments sprung on the 7th 9 mines (of 10 kilos of dynamite and 20 kilos of powder) in the embankment near Loevestein, where two ice-breakers arrived in the afternoon.

The Nieuwe and Boven Merwede were then cleared and open to navigation and one of the boats conveyed the second detachment.

A decision was taken on the 8th of that month that the detachments would attempt to break the ice beginning from the two shores while the ice-breakers would work in the same time. The detachments would have to go gradually higher up along the shores. In this way the rupture of the embankment soon took place. One of the detachments sprung 5 mines of powder of 10 and 15 kilos and one of dynamite of 5.5 kilos and the other 3 of 20 kilos (these last were fired all at once by electricity). The mass of ice till then unshakable was broken and rent in all directions of its downstream part beginning to move every where by the blasting and by the ramming of the ice-breakers. By the pressure of the water accumulating behind it the ice-bank gave way and was rapidly carried away by the current. One of the detachments occupied in making mines could not reach shore quickly enough and was carried away on blocks of ice and was only able to gain land one kilometre beneath with the sled boats by an open channel in the ice. The ice-breakers steamed downwards to find a refuge against the ice carried away by the stream. The river was now open unto the fort Vuren. There also was a barrier of ice and the detachments sprung on that same day a dozen of mines, while the ice-breakers assisted. A vast field of ice was cleared, but the barrier itself, although much reduced, did not give way immediately. The next day early in the morning it began to move and left the river open untill near Herwijnen. On the 9th of February the detachments went there to break the embankment. During the night the barrier near Zalt-Bommel floated down so that the Waal was now open excepting at Herwijnen. From the two shores 16 mines were sprung, (3 powder of 10 kilos and 8 of dynamite of $7^1/_2$ and 10 kilos on the right side) during which the ice-breakers also gave aid. There also the transparent and polished ice was totally crushed and transformed in a floating mass and the forward banks of ice destroyed.

During the work at half past one the whole mass cleared and the river cleared regularly.

On account of the movement of the ice from above it cannot be said with certainty that the clearing just described is the result produced by the mines and ice-breakers; but still we think so if compared with the similar clearings at Loevestein. Nevertheless it is probable that on account of the long thaw and subsequently the feeble cohesion of the ice, the clearing would have taken place without the artificial help.

3. The ice embankments in the Boven Rijn near Lobith during the winter 1892/1893.

To work efficaciously at the clearing of the Boven Rijn measures were taken according to the experience acquired during the preceeding winter.

The thaw set in on the 13th of January after a continued frost during three weeks, a detachment of 3 officers and 67 men was sent to Lobith. As it might happen that embankments would form themselves on the upper and lower ends of the discharge canal of the ancient mouth of the Rhine and that mines would have to be exploded, the detachment was divided in two companies who remained in communication by telephone.

The thaw that had set in did not continue as the following night it began again to freeze continually to the 22nd, then a regular thaw began. It was already then found prudent to reduce as much as possible the large embankment just below the frontier which did cause a rise of water of one metre between Lobith and Hulhuysen. The polished ice had an average thickness of 15 to 35 centimetres and that of the whole embankment did measure 1 to 5 metres.

Orders were given on the 24th to commence the clearing and on that day a mine was sprung at 250 metres beneath Km. stone VII. The following days the embankment between Aart-Binnen and Km. stone VI was attached vigorously. The number of mines sprung was 59 of 10 to 20 kilos of powder nearly all placed at 2½ metres beneath the surface of the ice. Mines were placed regularly spaced and normal to the direction of the river to keep a sufficient distance from the frontiers on the left and also from the fascine works of the right side.

The effects of some of the explosions have been given in the table II.

In general the openings produced were of 6 to 15 metres diameter. In some cases fissures of 30 metres were made. But to study the fissures was found impossible on account of the rough ice formed by blocks of ice heaped one on another and this could not be done without danger because of the water and ice coming through the openings; often no fissure was seen. Although it would have been rational to space the mines according to the length of the fissures, this was not possible for the above said reasons. Nevertheless these were placed as regularly as could be and even between the lines some extra ones were added where blocks of ice had heaped one on another.

On account of these difficulties and as only a part of the detachment could work the greatest number of mines fired in one day was but 23.

On the 28th of January at 6 o'clock in the morning, the ice before Lobith (Tolkamer) moved when the gauge marked 12.83 mètres + A.P. and after having caught twice moved away regularly. At half past twelve on the same day the Oude Rijnmond began to clear and the detachment was divided.

The 29th from 3 to $4^1/_2$ o'clock p. m. the ice began to float by a height of water 14.47 + A.P.; the 30th it kept moving from $1^1/_2$ till $2^1/_2$ o'clock. The detachments were on the alert that day.

The 1st of February at $2^1/_2$ o'clock p. m. the clearing commenced in reality by a height of water 14.59 metres + A.P. It is difficult to say to what extent the above described explosions contributed to the clearing. It can be stated that the first movement on the 28st of January that took place from above Wesel to a little lower down than Nimegue took place also near Bijland in a regular way and that the increase of flood level disappeared entirely during the day.

With other embankments in the Bijlandsch Canal no danger occurred.

c. The way to clear and to keep rivers open during frost.

We can be more concise as to the clearings done to open or to keep open the rivers during frost; it is only during the winter 1892—1893 that the troops of engineers have worked to attain that end. The circumstances under which the Nieuwe Merwede remained open during the period of frost and the plan made to that effect have been described in the preceeding chapter.

This is the way the plan was executed:

On the 15th of January the Hosanna and Freya began to work at the clearing, beginning at the lower part of the Nieuwe Merwede, meanwhile a detachment of one officer and 20 men arrived the preceeding day at Werkendam aided from the 16th to the 19th of January. By the means of 22 mines of $12^1/_{10}$ kilos of powder the gap made by the steamers was enlarged and the large blocks of ice floated down the river or were blasted when necessary.

On the 19th the work ceased the upper entrance being open; blocks of ice were only remaining heaped up on the sandbanks.

B. Means to make and explode the mines; the fitting out of the detachments.

To be able to judge properly of the results and utility of artificial clearings described in part A, we think it necessary to give a short description of:

a. The way the mines are made in this country;

b. The necessary equipment of the detachments and the way the work is arranged.

a. **Means to make and explode the mines** (see figure II).

These works being done rarely it is difficult to gather information for their best execution. Under the letter A we have mentioned the cases when it was found necessary to explode mines for clearings. We have seen that since February 1881 no such work was undertaken during a long period. Therefore the detachments commissioned in 1890—1891 had to work according to their own resources and ideas. The circumstances during the winters 1890—1891 and 1892—1893 were not similar as will have been seen. Therefore it must not be concluded that the different ways ot firing and making the mines depended upon personal conception. That is what we are going to describe more amply in the following part of this paper.

We will examine the kind of mines which have been used. As we have already seen powder has been as much employed as dynamite. The first is powder called n°. 1 or 2 in grains of 1.01 to 2.24 and 0.61 to 1.01 millimetres; the second is the kieselearth, containing about 75 % of nitroglycerine.

The charges of powder were contained in stone bottles, in tin boxes, barrels or small boxes hermetically closed. (1) As to the charges of dynamite they were generally used as they are found in trade (in cardboard boxes) containing 2½ kilos. Sometimes these were wrapped up in oilcloth, for instance when they had to remain for some time under water.

The mines were fired by electricity or in the usual manner. The equipment of the detachments allowed both ways to be used.

For the usual manner the BICKFORD match was employed. This consists in a waterproof envelope containing fine powder burning at the speed of one centimetre per second. This was simply attached to the charge passing through the cork that shut the boxes or bottles.

As to the charges of dynamite the trail has at its end a cap containing 1 gram of fulminate of mercury. This cap lights a sort of cartridge (figure 6) consisting of a small box in tin containing fulmi-cotton-dynamite. Sometimes the cap and cartridge were packed together in oilcloth attached to the end of the trail, all closely shut by paste. The length of the trail should enable to keep a distance of 100 to 150 metres In places where no ice was heaped under the surface ice and where mines were easily placed, the trail was lighted beforehand and in that case a trail of 1¼ metres was sufficient, in other cases the length was of about 3½ metres. Often two mines were fired at once in taking trails of the same length. In that way the effect is greater.

To fire the mines by electricity the exploder SIEMENS and HALSKE was used with isolated cables.

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(1) As for waterproof the tin boxes are the best envelopes. They suffer also less in being conveyed, while stone bottles broke or cracked often.

The conducting cables are attached to the cartridges primed for powder or dynamite (see figures 4 and 5) these were placed in the charges and if the dynamite was frozen a cartridge of fulmi cotton was annexed. The waterproof sealing and isolation are made by paste and oilcloth. By the means of electricity 2 or more mines were exploded at the same time by a combination in form of chaplet.

Other ways of uniting the mines caused refusals.

The engraving I represents a charge of powder under a small crust of ice. The stone bottle is fixed by a string to a lath on the ice and sinks in the water by its own weight. A Bickford trail of 1.25 m. has to fire the charge.

The mine represented by the engraving 2 was more difficult to place on account of the ice moving underneath. The tin box fixed to a cross in wood had to be driven in although a heavier weight had been given by ballast. The trail is tightly bound by wire to the opening of the charge in the box, the waterproof sealing having less chance of breaking. Also the end of the fuse 2½ metres long is only loosely bound to the lath so that it should not break. It is lighted only when the mine is placed.

The mine of engraving 3 is composed of 4 boxes of dynamite, tied together to a cross of wood. These are fired by electricity as represented by engraving 7, the conducting cables being attached to the lath. To place the charges a hole of 50 to 100 centimetres is made; a larger opening has its inconveniences as it renders it more difficult to fix the charge and also on account of the water easily forcing its way through the opening. When the thickness of the ice is small, the holes were made with hatchets or with a cartridge of 80 grams of dynamite. At places where heaps of ice exist 2 or several cartridges of dynamite are wanted. In 1891 charges of about ½ kilo were used with success. These charges were simply placed on the ice.

b. Force and composal of the detachments, equipments and regulation of the works

In general the detachments were composed of:

1 officer (lieutenant), 4 underofficers, 4 corporals, 12 soldiers (1) Such a division had an equipment as is described in table I and could dispose of boat-sledges (2 to 4) manned by experienced boatmen, (two per boat). The clearing was done under the direction of the respective government engineers; the regulations were drawn for each detachment by an engineer and inspector of the Waterstaat and the officer. The men were employed according to local circumstances. The regulation followed during the clearing of the Boven and Nieuwe Merwede in January 1893, was success-

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(1) When the importance of the works made it necessary the number was more important or several detachments worked together (Lobith 1893 and Nieuwe Merwede and Waal 1891).

ful. We take the following notes from the report made by the commander of the detachment:

„When no particular circumstance interfered, 2 underofficers and „2 corporals with 4 to 8 men, remained near the store house. This „gang made purchases and necessary conveyances also prepared the „charges for the following day. One of the corporals was especially „designed as storekeeper. A gang of 2 underofficers, 2 corporals, 3 or „4 soldiers of the Engineer corps and 6 to 8 boatmen were ordered „off to work on the ice in those cases.

„To have no delay in the works all was done not to have to „return to the store house during the day; to enable this 60 to 70 „charges were conveyed by two sledge-boats. The 3rd boat was used „for the stores while the fourth was used to keep communication „with the ice-breakers and the shore, also to survey the places where „the ice was strong enough to bear and examine the openings made „by the explosions.

„Two gangs of 2 to 4 men each were generally at work armed „with hatchets and pickaxes to make the holes and fix the charges. „If the ice was too hard 1 to 3 cartridges of dynamite were employed.

„Meanwhile one of the two boats carrying the stores was used to „place a charge near each opening. Two gangs of one or two men „prepared and fired the mines. The other soldiers were divided „according to necessity among the different boats".

With embankments of minor importance and when the clearing might eventually take place during the work, causing the men to be displaced at long distances during the same day, quite another method must be followed. In 1891 the detachment on the Waal had at its disposal several carts, one of which served as mobile store house; the charges were placed near the place where the men were at work The state of the ice and the certainty that it would soon give way obliged the men to remain near the boats, and it was found prudent not to load them with more than 6 charges at a time, it being possible to take a fresh load from shore. Each boat had one underofficer, 1 corporal, and one or two soldiers of the engineer troops with two experienced boatmen. It is useless to say that these boatmen are of the greatest utility. When the clearing begins while the men are on the ice and the retreat to the shore is cut off by a river floating impetuously with ice (this took place on the Waal near Loevestein) it would be impossible to save the soldiers without the aid of the boatmen.

C. Considerations on the results obtained; costs.

The results obtained in 1891 and 1893 will be more amply detailed in chapter VI, therefore we will simply resume the effects of the means employed. Under letter A we have mentioned the results of the works undertaken by the detachments.

As to the clearing of ice-banks it was proved that during the winter 1890—1891 the help of the mines to aid the ice breakers was insignificant (see chapter IV, sub A 2) this can be said of the work undertaken both on the Hollandsch Diep and on the Lek.

In general the great thickness of the ice obliged the mines to be placed nearer to one another (that is at a distance of about 25 metres) to enable the boats to break through from one opening to the other. The ice-floes don't float away regularly unless a large breach is made, to do this a great number of mines would have to be exploded.

For instance to open the Hollandsch Diep and Nieuwe Merwede on a width of at least 200 to 250 metres on a length of 1000 metres 320 to 360 mines had to be fired. It can be understood that under the most favourable circumstances only 40 mines could be placed per day. In that way it was impossible that the detachments would have sufficient advance on the boats.

More men on one point would not have given better results. It would have been possible by exception to let two detachments of a total strenght of 40 men work in the same section of the river of a length of one kilometre, thereby firing 80 blasts a day at the utmost. On the Lek the circumstances were more favourable but still many difficulties were encountered, wherefore it was decided to stop the blasting operations.

The work on the Boven Merwede and the Waal during the winter 1892—1893 had better results. The ice being less thick and the boats having ploughs the detachments did not meet with so many difficulties as two years before; by the experience acquired in 1891 the preliminary arrangements were better. The rapid progress in the clearings was the result also of the small width that had to be given to the channel on account of the low water (100 to 150 metres). But this must not be considered as an advantage as with such a width the clearing of the ice from above is not assured. The greatest number of mines exploded on one day was 59. As in general only 2 or three mines in one furrow had to be used, and as the furrows could be spaced at from 25 to 75 metres, considering further that in certain places the boats did not want the help of the miners it is to be understood that the work advanced rapidly. As to the results obtained during the last winter these were generally satisfactory.

We read in the report of the winter 1890—1891, page 70: „The „breaking down of ice embankments seems to be reserved specially to „miners". In the report of 1892—1893 page 76 we note the following words: „the greatest services rendered by the troops of Engineers are the „rupture of heaps of ice and the enlarging of the gaps made by the steamboats „across shallow parts where these could not reach; and further at the page 94:

„Also that what has happened when clearing the embankment in the „Lek near Nieuwpoort, shows that exploding mines is successful for small „embankments".

The reducing of the great barriers near Zalk 1891 and Lobith 1893 did not result in a regular clearing immediately as will already have been seen by the description made but still it seems that the mines exploded did favour the clearing.

We will now examine the observations made upon the use of explosives and the means of firing these.

Powder and dynamite.

If before 1891 powder was generally used it was on account of the small effects of the dynamite and of the difficulty to explode it but still the last years experience has changed this opinion.

The inconvenience of the greater difficulty to explode dynamite is overcome by the detonators of gun-cotton which fire it even when frozen and there above dynamite has the advantages of not being hurt by its exposure in the water while powder becomes often useless.

This simplifies very much the employment of dynamite which demands much less time as it can be used as it is packed by the makers (card boxes). Powder necessitates packing in waterproof covers and this demands more conveyance of material.

The effect must be the principal motive to determine the choice. Different circumstances have on this account more or less influence: the thickness of the ice, presence of ice underneath the usual above ice; depth of water, state of the ice since the preceding explosions and also the width of the opening through which the charge has to be passed. This renders a comparison very difficult (see table II). In general after the work done during the year 1891 the opinon was that mines of powder had more effect on ice embankments than a corresponding quantity of dynamite especially in producing fissures. This is explained by the more rapid explosion of the dynamite; a rapid shock agitates the water less, than a long shock although less violent. The gasses produced by an explosion of dynamite are more rapidly absorbed by water (that is the reason of the charges of dynamite being placed less deep in the water than those of powder). We read in the report made by the commanding officer of the detachment who took part in the clearing of the Boven Merwede:

„Charges of powder and dynamite were alternately employed on ac-
„count of the difficult conveyance of sufficient powder for the whole day.
„According to statements made no practical difference is remarked in the
„production of openings or fissures between charges of $12^1/_2$ kilos of pow-
„der and $2^1/_4$ kilos of dynamite."

It will be necessary to examine more attentively the question in following occasions and also in consideration of the use of dynamite to blast solid ice walls. Herefore it seems to have been proved that it is preferable to powder on account of its destructive power. To reduce vast embankments by making fissures powder has often been used (Zalk 1891, Lobith 1893).

Firing by fuse or by electricity.

In general the Bickford match is preferable to electricity as it necessitates less expenditure of time.

The placing, the transport, the continual inspection, the cleaning of extremeties as well as the joining of wires cause much delay especially when the work has to be done by means of sledge-boats. The exploders and cables restrain also the space of the boats and suffer much by use.

Occasionnally the firing by electricity is to be recommended as was principally the case in blasting the great embankment at Zalk where the holes made filled immediately with ice. When is these cases the trails Bickford were employed long ends were necessary (at least as long as the charge is deep in the water) as these cannot be lighted before the charges have reached their necessary depth, by the long time the fire takes before reaching the mine, the chances of moisting the charge are enhanced if the connections should not be hermetically sealed.

In the case mentioned above there was no danger of the ice giving way, whereby the work was performed in safety without the necessity of of coiling the wires every time they had to be shifted as the men could freely leave the boats.

In case of imminent peril by the embankments on account of the high pressure of water which case however did not occur of late it might be desirable to use the electric exploder from the shore so that the men can get clear of danger before the explosion. This way can also be advantageous to fire different mines at the same moment which can produce good effects in the cases of embankments.

It will thus always be preferable before choosing to consult the circumstances.

As to the expenses of the blasting, which is of course the main factor, we will mention that during the winter 1890—91 297 mines were fired for which 594 k^{os}. of dynamite and 3531 k^{os}. of powder were used. The expenses with the costs of lighting material were 6000 fl. The total expenses, material and salaries amounted to fl. 13000. In this sum the costs of conveyance by railway and the expenses of the officers are not included, these can be estimated at fl. 1500.

The cost per mine averaged fl. 51.50.

During the winter 1892—1893 439 mines were fired for which 417 k^{os}. of dynamite and 5623 k^{os}. of powder were used. The expenses with the costs of lighting material were about 7000 fl. The total expenses amounted to fl. 16940 and the costs of conveyance by railway etc. estimated at fl. 2000 would make each mine cost in average about fl. 43.

VI. GENERAL CONSIDERATIONS.

If the results acquired by experience during the different attempts to accelerate the clearing are well considered, it will be seen that the great difficulty resides in the blasting of embankments and that this work is of high importance.

In the lower parts of rivers the tides are the most persisting cause of the forming of ice embankments; but these accumulations are formed also in the upper parts of rivers and here as well as in the lower parts by preference where the river has an irregular course.

Thus to regulate the rivers would most certainly be the best means to reduce in future the artificial clearings.

If the ice-field is composed of hard ice of 20 centimetres thick, under which occasionally layers of ice are found of 50 to 80 centimetres, it will not be necessary to have recourse to mining, the boats used as ice-breakers will suffice. But if the upper ice is thicker and the ice underneath accumulates more and more the work will be quicker done by the aid of mining. This last method will have to be practised exclusively if the ice-breakers cannot reach the embankments.

As to the work being done by ice-breakers, it must be abandoned if the steamboats are not specially constructed for this work. The use of others does not only hinder the work but provokes costs of repairs excessively high.

As has been shown here above the expenses amounted during the winter 1890—91 to fl. 40150 and in 1892—1893 to fl. 29300.

It is preferable to commence work only when a continued thaw has set in. Occasionally circumstances may render desirable to begin working before the frost has ceased, this was the case during the winter of 1891—1892.

The work must take place only against stream; in the tidal parts of the rivers during ebb. The loosed ice can then float downwards which is indispensable for the ice-breakers to avoid damage to the rudder, screw or paddles.

Night work is impossible even with electric light as one cannot survey the whole situation.

The electric light on board of the ice-breakers is only to be used in case of distress.

One ice-breaker must never work separately, two or three must work together. If the ice is rather thick an ice-breaker in working alone finishes in being unable to clear itself as the ice-floes along the sides of the steamer cannot always find an issue, and continual delays are the consequence. If two or three steamboats work together the breach made by the first can be enlarged by the one following and in that way the ice can float away.

It is also necessary that at least two boats work together as one very often penetrates too far to return or gets aground in shallow water.

In the part of the river where it is intended to clear the ice, the floating ice must be prevented from forming a compact mass; that work must be done daily on the whole width of the river as far as the depth of water will allow. The steamboats with the greatest draught should lead in the channel of the stream, the smaller craft following to enlarge the opening as much as possible.

As soon as the part of the river where the ice is broken is open on its whole width as far as can be, it must not be neglected to make the steamboats run at full speed along the ridge of firm ice several times and as close to it as possible; in this way fissures are made in the ice still attached to the shore and as a rule large floes will break loose and float away.

Also each day at least two ice-breakers should run in all directions through the open part from the point where the work started to the ridge of firm ice, in order that the ice floes drift away without heaping up anywhere.

This way of working necessitates at least five ice-breakers for the clearing of a river until the work is so far advanced that two steamboats cannot run up and down in one day the part of the river that has been cleared. Then the number of ice-breakers must be increased.

The work should be conducted in such a way that the steamboats may pass the night at safe moorings. In leaving these boats in the middle of the river during the night they are exposed to great danger and great damage in case of an unexpected breaking up of the ice.

Concerning the question if the steamboats with paddles or screw are preferable it can be remarked that the movement produced in the water by the paddles is favourable for the rupture of the ice round about but on account of their great width paddle-steamers advance with great difficulty in firm ice and have to struggle harder to get clear of it. Considering that the screw steamboats also move the water heavily and that the screws if well and strongly made in cast steel and of appropriated form are less exposed to be damaged, the preference will be given to these steamboats.

As to the work done by blasting we will still mention what follows:

We have seen that if intended to prepare the way for the ice-breakers the mines should be sufficiently spaced, to keep wel ahead of the ice-breakers when clearing the lower part of a river.

If this condition can be fulfilled the results to be expected in future depend mainly on the good construction of the ice-breaker.

From the experience acquired in preceding winters we draw the conclusion that the use of exploding mines can only be recommended when on a distance of one kilometre. 40 to 50 mines can be exploded per day and when spaced at a distance of 75 metres in average.

It is true that in these cases the fissures will not meet but the effect produced will always greatly contribute to the progress of the steamboats.

If during the frost sufficient preparations have been made to enable work to begin immediately at the beginning of the thaw it will undoubtedly be possible to fire 40 to 50 mines per day with a detachment of 20 men. A corps of 3 officers and 67 men, such as has been ordered in 1893 to work in the Boven Rijn, should be able to make openings on a distance of 3 kilometers and a width of 200 to 250 metres daily, that is a distance twice as long as could be cleared daily in 1893 on the Boven Merwede and the Waal under fairly favourable circumstances.

If in following the above method, the strength of the ice-breakers might prove insufficient, the conclusion that mines used in those circumstances are useless would be according to our idea, quite true.

We believe that we can express with more certainty a judgment upon the use of explosives for ice of little thickness. The clearing of the Boven Merwede described precedingly has proved that if the work is done with tact, favorable results can be obtained even with the actual resources. A greater success can be predicted when special constructed ice-breakers will be used.

It has been proved more than once that blasting operations to destroy partially the barriers are possible and favorable to clearings. To what extent the utility is proportioned to the expense and danger cannot be said but the utility can still be admitted. Neither is it possible to predict what would have happened if blasting had not been had recourse to, or wether it will prove to be of much use in very serious cases. We donot expect much from it when the ice in the upper rivers breaks up in time of flood, the rapid rising of the water occasioning the formation of ice-banks every where and threatening to burst the dikes. It would however not be fair to judge the merits of the system by such circumstances, which happily recur only very rarely.

We believe therefore that it is desirable to continue with the blasting of ice-banks, as only a longer practice and careful observations will show the way for further improvements.

The men employed for these works should be sent in time on the spot of action to enable them to examine the local conditions, study the river, and if necessary to prepare workshops and store houses. It is essential to provide in good time means of conveyance for the explosives and it would be desirable to construct small storehouses on the points where embankments usually are formed and where artificial clearances often have to be performed (Nieuwe Merwede) if the points are not handy to get at.

As regards the expenses of blasting operations we still remark that though it may be possible to reduce the costs involved by the uce of ice-breakers by a more appropriate construction, this will not be the case with those caused by the blasting.

Some economy may be attained by cheaper plant and materials but the general expenses of salaries, wages and explosives will become larger by the way of working we have recommended.

The following notes can be still added.

If the state of the ice permits the works of artificial clearing to advance rapidly it can be pretended that in such a case these works are unnecessary; because in general the natural clearing will take place without the interposition of human aid and without danger for the surrounding districts. But on account of our ignorance of complications that can take place it cannot be denied that even then artificial clearing might be useful.

It has happened that during the same winter, two or three periods of frost were interrupted by longer or shorter periods of thaw. In these cases it seems to be necessary that the heaps of ice in the lower parts of the river be destroyed, whereby without any doubt the embankments that might be formed later on are less dangerous.

If the barriers of ice become very dangerous, as they did during the winter 1890—1891, and if under such circumstances the situation becomes still more serious by the ice in the Rhine in Germany breaking up at the moment of an great increase of water while here the rivers are still frozen over, it can certainly be said that all artificial clearing although undertaken with the greatest energy and every perfection of the implements used, will be quite helpless to produce any appreciable influence.

The history of the severe winter seasons in Holland learns us that during the years when inundations happened, only 3 to 4 days difference existed between the first movement in the ice of the lower Rhine in Germany from Wesel to Emmerich and the time when the dikes which protect the districts above Rhenen and Tiel did burst.

In those cases the points threatened cannot be reached in good time by ice-breakers that must push their way up from the mouths of the rivers. The use of explosives will have but small utility as long as the ice heaped up below is not carried away.

VII. Conclusion.

The conclusion of what precedes is that one must not exclude the possibility of impeding the formation of ice embankments in our rivers when the winter is not too severe and to break the barriers that will form in a more or less considerable quantity, but with severe frost it will soon be seen that this is impossible.

In general it does not seem to be desirable to make attempts of artificial clearings in the interest of interior navigation as the boats used in such navigation will be unable to push their way through the floating ice. The boats of wood are utterly incapable to navigate our rivers when the ice floats in rather great quantities and even iron boats would soon be so damaged as to be obliged to run for refuge. To modify the construction of these boats that they be capable of resisting against floating ice would most likely cost too much.

If the clearing of the large canals and sea ports has serious advantages for sea navigation, the interior navigation will profit very little except in particular circumstances by the works of artificial clearing on our rivers.

Table I.

EQUIPMENT.

- 20 woolen costumes; viz. 1 under jacket, 1 trowsers and 1 cravat.
- 20 powder mats in horse hair.
- 1 ice saw.
- 2 torchstands.
- 1 case containing:
    - 500 metres Bickford trail (62½ coils).
    - 5 „ oil cloth.
    - 20 balls of paste.
    - 2 shovels.
    - 1 hand saw.
    - 1 crowbar.
    - 1 sledge hammer.
    - 1 hand hammer.
    - 1 wimble with 6 piercers.
    - 1 pair of pincers.
    - 1 hammer (copper)
    - 1 turrel („) } coopers tools.
    - 1 knife („)
    - 1 driver („)
    - 4 kilos of nails 2, 3 and 4 inches.
    - 2 sacks of tools containing each: a knife, file, shears, pincers, a rule, a ball of string, a ball of brasswire and 2 sheets of emery paper.
    - 2 pots for boiling pitch, with stove and trivet.
    - 2 measures for powder.
    - 2 boxes id. id.
    - 4 k^{os} of string.
    - 2 „ „ flax.
    - 5 „ „ marline.
    - 2 lanterns with two packets of candles for each.
    - 2 small lanterns.
    - 2 peel parafine torches.
    - 1 packing-needle.
    - 1 can for parafine.
    - 1 tape (20 metres).
    - 1 signal trumpet.
    - 2 grapples with cords.
- 1 box of 200 caps of 1 gram.
- 2 boxes containing each 100 cartridges (primers).
- 1 „ „ „ 50 detonators (electric for dynamite).
- 2 „ „ „ 100 „ (id. for powder).
- 1 exploder.
- 2 coils of 500 metres each conducting cable.
- 1 cylinder barrow to roll the cable.
- 20 tin boxes, to contain each 20 litres.

Table II.

Results of blasting operations.

Reference number.	DATA of the explosion.	SUBSTANCE.	Weight in kilos.	POSITION.	
				Kilometre stone.	side of the channel and distance from the shore.
				Mines at the lower mout	
1	1th February	stone bottle of powder	15	kilometre stone CXXIII	30 m. on the south
2	„	dynamite in boxes.	3,5	150 m. above kilom. stone CXXIII	30 „ „ „ „ „
3	„	stone bottle of powder	20	350 „ „	in the channel
4	2d „	dynamite in boxes	10	650 „ „	30 m. south
5	3d „	stone bottle	25	350 „ above kilom. stone CXXII	175 „ „
6	„	„	10	500 „	150 „ „
7	5th „	„	10	500 „ „	50 „ „
				Mines at the lowe	
8	28th January	stone bottle of powder	12,5	650 m. below kilom. stone CXXX	near the channel
9	„	„	23	550 „ „	„
10	29th „	„	12,5	255 „ „	„
				Mines exploded in the Bove	
11	23th January	stone bottle of powder	12,1	150 m. below kilom. stone CI	90 m. from the right shore
12	„	tin box with powder	25	110 „ „	90 „ „
13	„	dynamite in card box	2,5	110 „ „	40 „ „
14	„	tin box with powder	25	430 „ above kilom. stone CL	90 „ „
15	24th „	dynamite in card box	2,5	70 „ „ C	40 „ „
16	„	„	2,5	140 „ „	30 „ „
17	„	„	2,5	280 „ „	30 „ „
18	„	„	2,5	280 „ „	100 „ „
19	„	„	2,5	350 „ „	30 „ „
20	„	„	7,5	40 „ „ XCIX	30 „ „
21	„	tin box with powder	25	40 „ „	25 „ „
22	„	dynamite in card box	7,5	100 „ „	50 „ „
23	„	„	10	100 „ „	70 „ „
24	„	„	5	180 „ „	100 „ „
25	25th „	„	5	240 „ below kilom. stone XCVIII	50 „ „
26	„	„	5	240 „ „	70 „ „
27	„	„	5	240 „ „	110 „ „
28	„	„	2,5	160 „ „	110 „ „
29	„	„	2,5	160 „ „	70 „ „
30	26th „	tin box with powder	25	210 „ above kilom. stone XCVIII	50 „ „
31	„	„	25	210 „ „	90 „ „

Depth		Thickness of the ice in metres.	State of the ice.	Broken surface.		Broken and fissured surface.		NOTES.
in metres.	of the charge under ice in metres.			Length in metres	Width in metres	Length in metres	Width in metres	
f the Nieuwe Merwede (1891).								
14	1,75	0,36	polished and hard ice	11	11	10	15	The thaw began the 24th of January so that the hard ice has been greatly softened at the beginning of the works.
14	1,50	0,36	„	8	9	7	7	
15	2	0,40	„	12	14	50	50	
15	1,50	0,25	„	9	10	10	10	
4	1,50	0,50	uneven surface (not hard)	7	7	30	30	
4.5	2	0,20	„	12	12	50	50	
4	2,50	1,50	polished surface (not hard) under which ice was found in heaps.	8	8	no fissures.		
outh of the Leck (1891).								
5.5	2	0,25	extraordinary hard ice	6	6	fissures of 30 to 50 metres but ice keeping together.		
7	3,50	0,28	„	4	4			
5	3	0,17	hard ice	6	6			
erwede and in the Waal (1893).								
10	2	0,35	clear (hard)	7	7	30	30	thaw began the 22d of January.
10	2.5	0,35	„	10,5	10,5	20	20	
10	1	0,35	„	8	8	30	40	
4.9	2.5	0,30	„	12	12	30	40	
4.6	1	1,20	flakes of ice under the upper ice	3	3	10	20	beginning of ice-embankment.
4.3	1	1,70		3	3	10	20	
4.3	1	1		4	4	30	30	
4	1	0,70		4,5	4.5	30	30	
3.9	1	0,34	clear (hard)	8	8	50	50	
7.8	1	5		7	7	30	50	barrier.
8	1	6	pieces of ice under the upper ice	3	3	no fissures		
7,5	1	4		5	5	30	30	
6.9	1	5		5,2	5,5	30	25	
7.1	1	3		7	7	20	20	
5.6	1	2		10	10	20	25	
5.7	1	2,10		10	9	30	20	
5.7	1	2,10		10	11	30	30	
5.7	1	0,70		8	9	25	25	
5.6	1	0,65		10	10	20	20	
5.1	2,5	0,50	clear	15	15	20	20	
5.1	2,5	0,40	„	15	15	20	20	

Reference number.	DATA of the explosion.	SUBSTANCE.	Weight in kilos.	POSITION.	
				Kilometre stone.	side of the channel and distance from the shore.
32	26th January	tin box with powder	25	400 m. above kilom. stone CVIII	50 m. from the right shore
33	„	„	25	400 „ „	90 „ „
34	„	dynamite in card box	2,5	360 „ above kilom. stone XCVII	90 „ „
35	„	„	2,5	440 „ „	50 „ „
36	„	„	2,5	440 „ „	90 „ „
37	27th „	stone bottle with powder	12,1	500 „ below kilom. stone XCIV	30 „ „
38	„	„	12,1	500 „ „	110 „ „
39	„	„	12,1	440 „ „	110 „ „
40	„	„	12,1	440 „ „	30 „ „
41	„	„	12,1	380 „ „	30 „ „
42	„	„	12,1	380 „ „	110 „ „
43	„	„	12,1	320 „ „	30 „ „
44	„	„	12,1	320 „ „	110 „ „
45	„	„	12,1	260 „ „	30 „ „

Mines in the Geldersch

46	27th January	2 stone bottles with powder	27	252 m. below kilom. stone CVI	35 m. left of the channel
47	„	stone bottle with powder	18	252 „ „	70 „ „
48	„	„	9	252 „ „	45 „ „
49	„	„	50	217 „ „	30 „ „
50	„	dynamite in card boxes	5	217 „ „	5 „ right of the channel
51	28th „	cask with powder	50	217 „ „	65 „ left of the channel
52	„	„	50	187 „ „	61 „ „
53	„	„	50	187 „ „	21 „ „
54	„	„	50	187 „ „	16 „ right of the channel
55	„	stone bottle with powder	18	132 „ „	30 „ „
56	„	„	18	132 „ „	17 „ „
57	„	„	18	132 „ „	4 „ „
58	„	„	18	132 „ „	10 „ „
59	„	„	18	132 „ „	32 „ „
60	29th „	„	18	40 „	3 „ „
61	„	„	9	40 „ „	12 „ left of the channel
62	„	„	18	40 „ „	27 „ „
63	„	„	9	40 „ „	42 „ „
64	„	„	18	40 „ „	57 „ „
65	30th „	„	9	5 „ above kilom. stone CVI	3 „

	p t h			Broken surface.		Broken and fissured surface.		
	of the charge under ice in metres.	Thickness of the ice in metres.	State of the ice.	Lenght in metres	Width in metres	Length in metres	Width in metres	NOTES.
	2,5	0,60	ice heaped up	12	12	20	30	
	3,5	0,65	„	12	12	25	30	
	1	0,35	clear	7	7	13	13	
0	1	0,32	„	8	8	15	15	
0	2	0,30	„	8	8	15	20	
0	2	0,30	„	8	8	15	15	
0	2	0,34	„	7	7	15	20	
0	2	0,34	„	6	6	15	20	
0	2	0,32	„	6	6	20	20	
0	2	0.32	„	7	7	20	20	
0	2	0,34	„	7	7	20	20	
0	2	0,34	„	6	6	15	15	
0	2	0.40	„	7	7	15	20	
5	2	0.40	„	6	6	15	15	

***sel near Zalk* (1891).**

	2,90	0,40	polished ice (very hard)	11	9	30	30	
0	1,70	0,50	„	10	10	10	10	
0	2.05	0,55	„	9	9	9	9	
5	3,45	0,45	idem, underneath 1.3 m. ordinary ice	10	10	50	50	all fired separately
5	2,40	0.40	polished ice, very hard, underneath 1.1 m. ordinary ice	5	5	5	5	
0	1,90	0,40	polished ice, very hard	11	11	11	11	
0	1,90	0,40	„	13	13	13	13	
0	4,10	0,35	idem, ordinary ice 1.15 m. (underneath)	10	10	22	22	fired together by electricity.
0	4,65	0,40	„ 0.7 „	10	10	10	10	
	2,35	0,35	„ 0.85 „	9	9	13	13	
0	2,65	0,65	„ 1.45 „	10	10	12	11	fired together by electricity no. 57 sprang but slightly having most likely been too damp.
0	2,35	0,35	„ 0.75 „	-	-	6	6	
0	2,40	0,40	„ 0.40 „	9	9	12	12	
0	2,50	0,50	„ 0.90 „	10	10	11	11	
0	2,90	0,40	polished ice, rather hard	7,5	7,5	17	17	
0	2,90	0,40	upper ice, 0,90 m. ordinary ice underneath	5,5	5,5	15	15	fired all together by electricity.
0	2,95	0,45	„ ordinary ice 1.65 m. „	6	6	16	16	
0	2,80	0,30	„ „ 2.05 „ „	5	5	15	15	
	2,95	0,45	„ „ 1.25 „ „	7	7	27	27	
	2,85	0,35	„ „ 2.65 „ „	4	4	10	12	

Reference number.	DATA of the explosion.	SUBSTANCE.	Weight in kilos.	POSITION.	
				Kilometre stone.	side of the channel and distance from the shore.
66	30th January	stone bottle with powder	9	5 m. above kilom. stone CVI.	18 m. left of the channel
67	31st „	cask with powder	18	85 „ „	15 „ „
68	„	stone bottle with powder	9	85 „ „	30 „ „
69	„	„	9	85 „ „	45 „ „

Mines on the Wa

Reference number.	DATA of the explosion.	SUBSTANCE.	Weight in kilos.	Kilometre stone.	side of the channel and distance from the shore.
70	4th February	stone bottle with powder	23	about in the line above tile-kiln east of Haaften	about 150 m. from the rig shore in the middle of t channel.
71	„	dynamite in card box	2,5		
72	„	stone bottle with powder	23		
73	„	„	12		
74	5th „	dynamite in card box	2,5		
75	„	„	2,5		
76	7th „	dynamite in card boxes	5		
77	„	„	5		
78	„	„	10		
79	„	„	10		
80	8th „	stone bottle with powder	17	100 m. lower down.	
81	„	dynamite in card box	2,5		

Mines on the Waal near Loev

Reference number.	DATA of the explosion.	SUBSTANCE.	Weight in kilos.	Kilometre stone.	side of the channel and distance from the shore.
82	7th February	dynamite in card boxes	10	500 m. above kilom. stone XCIV	150 m. from the left shore
83	„	„	10	500 „ „	10 „ south west of n°. 82
84	„	„	10	500 „ „	20 „ „
85	„	„	10	500 „ „	30 „ „
86	„	„	10	500 „ „	40 „ „
87	„	stone bottle with powder	20	530 „ „	above n°. 82
88	„	„	20	530 „ „	„ 86

Depth in metres	of the charge under ice in metres.	Thickness of the ice in metres	State of the ice.	Broken surface. Length in metres	Width in metres	Broken and fissured surface. Length in metres	Width in metres	NOTES.
,1	2,95	0,45	upper-ice, underneath 2.25 m. ordinary ice	5	6	18	12	
.30	2,80	0,30	upper ice, rather soft	6	7	30	20	fired together by electricity.
.45	2,85	0,35	idem, 0,95 ordinary ice underneath	6	6	25	20	
.35	2,80	0,30	„ 1,60 „	7	6	30	20	

ar Zalt-Bommel (1891).

	2	0,20	soft, polished, partly broken ice, nowhere strong enough to bear a man safely.	The ice is heaved up without breaking; much ice floating in the river.				
	on the ice 1	underneath much ordinary ice.		Ten metres square of ice is carried away in front. 8	8	12	12	
	1	0,75		5	5	river carries very much ice.		
	0,50	0,50		8	8	fissures 15 m. from the middle.		in placing the mines, ice thrusts itself in the holes coming from the preceding explosions.
to 7	1	1,50		8	8			
	0,50	0,50		8	6	not noted.		sprung together the river floats ice during $^1/_2$ hour.
	0,50	much ice underneath		8	7			
	0,50			ice-floes coming down				
	0,50			10	10	ice at the back gives way; large blocks float away		
	0,50	0,20		6	6			
	0,50	0,20		6	6			

in, Vuren and Herwijnen (1891)

0	flakes of ice underneath	2	1.2 m. broken ice, further on ordinary ice	13	10	20	15	
		2		8	8	20	12	
		2		10	10	20	12	
0		0,40		9	9	7	8	
		0,40	thick massive ice	not noted				
	2	0.30		the ice-bank shaken by the mines 82 to 88 is taken away by the current				
0	2	0,30						

Reference number.	DATA of the explosion	SUBSTANCE.	Weight in kilos.	POSITION.	
				Kilometre stone.	side of the channel as distance from the shore.
89	8th February	stone bottle with powder	20	at the height of the ferry at Loevestein	25 m. right side
90	„	„	20		50 „ „
91	„	„	20		75 „ „
92	9d „	„	10	500 m. below the house called „de Hoek" at Herwijnen	50 „ left side
93	„	„	10		25 „ „
94	„	dynamite in card boxes	10		50 „ right side
95	„	„	10		50 „ „
96	„	„	7,5	25 m. above idem	10 „ „
97	„	„	7,5		35 „ „

Mines on the Ma

98	25th January	stone bottle of powder	15	110 m. below kilom. stone XLVIII	13 m. left side
99	„	„	18	110 „ „	8 „ right side
100	„	„	18	110 „ „	29 „ „
101	„	box of dynamite.	2,5	110 „ „	44 „ „
102	26th „	stone bottle with powder	15	25 „ „	54 „ left side
103	„	„	18	25 „ „	39 „ „
104	„	„	18	25 „ „	24 „ „
105	„	„	18	75 „ „	42 „ „
106	„	„	18	75 „ „	27 „ „
107	„	„	23	75 „ „	12 „ „
108	„	„	23	75 „ „	3 „ right side
109	28th „	dynamite in card box	2,5	kilometre stone XLVIII	63 „ „
110	„	stone bottle with powder	18	„	84 „ „
111	„	„	15	25 m. above kilom. stone XLVIII	73 „ left side
112	„	„	18	25 „ „	58 „ „
113	„	„	18	50 „ „	66 „ „
114	„	„	18	50 „ „	51 „ „
115	30th „	tin box with powder	23	50 „ „	39 „ right side
116	„	„	20	980 „ below „	30 „ „
117	„	„	26	940 „ „	40 „ „

Depth in metres.	 of the charge under ice in metres.	Thickness of the ice in metres.	State of the ice.	Broken surface. Length in metres	 Width in metres	Broken and fissured surface. Length in metres	 Width in metres	NOTES.
	2	0,30 to 0,50	under the upper ice other ice was found	20	20	many fissures of 50 m. in all directions.		all fired together by electricity.
3,50	2			20	20			
3,50	2			20	20			
,50	2	average 0.40	under the upper ice there was 1 mètre 50 of other ice	14	14	many fissures of 100 m. united to the openings		
,50	2			14	14			
,50	2			10	12			
,50	2			10	12			
,50	2			10	12			
,50	2			10	12			

ar *Woudrichem* (**1893**).

,50	2	0,28	2,6 m. ordinary ice under upper ice.	5	7	10	8	
,80	2,50	0,30	3 „ „	10	12	6	5	
,50	1,50	0,30	3 „ „	8	8	6	5	
	1,25	0,30	2 „ „	6	5	10	8	
,50	2	0,20	2,3 „ „	8	10	8	8	
,30	2,50	0,25	1,8 „ „	10	25	6	6	fired together by fulmi cotton forming a hole with large concentrated fissures.
,90	2,50	0,25	1,8 „ „					
50	1,50	0,26	2,5 „ „	10	8	10	12	fired together.
50	1,50	0,21	2,4 „ „	12	10	8	10	
50	1,50	0,28	2,4 „ „	15	10	15	15	idem.
80	1,50	0,25	3,3 „ „	15	12	15	18	
	2,50	0,23	1,5 „ „	15	18	—	—	idem.
75	2,50	0,20	0,75 „ „	5	5	25	25	
50	2	0,20	3,2 „ „	6	5	—	—	idem.
80	2	0,32	2,4 „ „	8	10	—	—	
10	2	0,25	2,8 „ „	10	10	30	20	
40	2	0,35	1,8 „ „	10	8	6	6	
50	2	0,25	1,6 „ „	8	8	12	12	
re- an	2	0,30	no ordinary ice.	10	10	15	25	clearing of a field of ice.
a.	1,50	0,25	„	8	8	10	25	idem.

Mines on the Boven-l

Reference number	DATA of the explosion.	SUBSTANCE	Weight in kilos.	POSITION. Kilometre stone.	POSITION. side of the channel at distance from the shore	
118	25th January	tin box with powder	10	190 m. below kilom. stone VII	95 m.	
119	„	„	10	190 „ „	120 „	south of the shore
120	„	„	10	125 „ „	120 „	
121	„	„	20	125 „ „	80 „	
122	„	„	20	kilometre stone VII	120 „	
123	„	„	20	„	80 „	
124	26th „	„	10	430 m. below kilom. stone VI	90 „	
125	„	„	20	375 „ „	40 „	
126	„	„	20	375 „ „	80 „	
127	„	„	20	375 „ „	120 „	
128	27th „	stone bottle with powder	10	940 „ „	—	
129	„	tin box with powder	20	940 „ „	90 „	
130	„	stone bottle with powder	10	940 „ „	60 „	
131	„	tin box with powder	20	560 „ „	120 „	
132	„	stone bottle with powder	10	560 „ „	90 „	
133	„	tin box with powder	20	560 „ „	60 „	

ear Lobith (1893).

Depth		Thickness of the ice in mètres.	State of the ice.	Broken surface.		Broken and fissured surface.		NOTES.
in mètres.	of the charge under ice in mètres.			Length in mètres	Width in mètres	Length in mètres	Width in mètres	
—	2,50	0,60		8	8	—	—	It was difficult to determine the broken and fissured surface; that is the reason why this column has not been filled in excepting no. 120.
—	2,50	0.60	heaped up ice					
—	2,50	1		12,5	12,5	fissures at, about the distance of 100 m.		
—	2,50	2		12	12	—	—	
6	2,50	1		12,5	12,5	—	—	
,70	2	2		12	12	—	—	
	2,50	0,20	underneath ordinary ice 1.5 m.	7	7	—	—	
	2,50	0,18		9	9		—	
,50	2,50	2	heaped up ice.					
	1	2,50		11	11	—	—	
,50	2,50	0,20 2,50	hard ice. heaped up ice.	8	8	—	—	
	2,50	0,15 3,50	hard ice. heaped up ice.	13,5	13,5	—	—	
,50	2	0,10 2,50	hard ice. heaped up ice.	8	8	—	—	
,20	2,50	2	heaped up ice	10	10	—	—	
,20	2,50	2,50		9	9	—	—	
	2,50	2,50		6,5	6,5	—	—	

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Inscriptions des Planches.	Inschriften der Zeichnungen.	Description of the Plates.
PLANCHE I.	BLATT I.	PLATE I.
Le „Wodan" avec brise-glace.	Der „Wodan" mit Eispflug.	The *Wodan* with ice-breaker.
Brise-glace du type „Elbe".	Eisbrechdampfer von der Elbe.	Sce-breaker of the *Elbe* type.
Echelle.	Maasstab.	Scale.
Dessins représentant la condition dans laquelle se trouvent plusieurs fois les rivières néerlandaises remplies de la surface au fond de glaçons glissés les uns sur les autres.	Darstellung des Zustandes, in welchem sich bisweilen die niederlandischen Ströme befinden, wenn dieselben bis auf Grund mit übereinander geschobenenem Eise verstopft sind.	Cut showing the condition frequently met with in Dutch rivers when they are filled from the surface to the bottom with pieces of ice sliding over each other.
Des pareils encombrements ont une longueur de plus d'un kilomètre.	Derartige Verstopfungen dehnen sich über mehr als einen Kilometer Länge aus.	Similar obstructions have a length of more than one kilometre.
PLANCHE II.	BLATT II.	PLATE II.
Câbles isolateurs.	Isolirte Leitungsdrähte.	Isolated cables.
Pâte.	Verschmierung.	Wax, paste or putty.
Toile d'infirmerie.	Verbandleinwand.	Lint.
Cartouche électrique.	Elektrische Patrone.	Electric cartridge.
Cartouche alumeuse.	Entzündungspatrone.	Inflamable „
Grandeur naturelle.	Natürliche Grösse.	Actual size.
Conduit sousterrain.	Unterirdische Leitung.	Subterranean wire.
Bobine.	Drahtspule.	Coil.
Détonateur.	Zündapparat.	Blasting cap.
Mines.	Minen.	Mines.
Saucisson Bickford.	Bickford-Zündschnur.	Bickford fuse.
Capsule.	Zündhütchen.	Cap.
Rouleau de dynamite.	Dynamitpatrone.	Dynamite cartridge.

Schuurman & Burgdorffer

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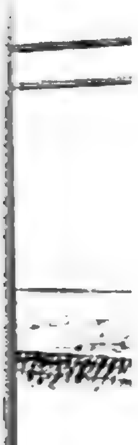

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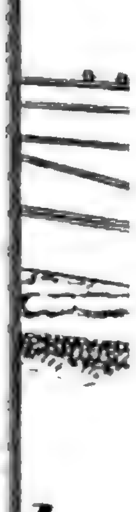

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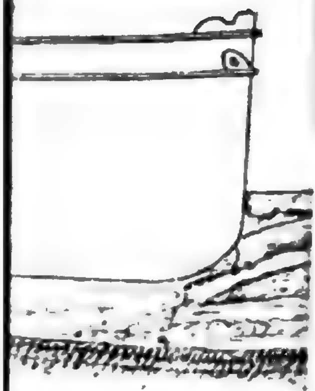

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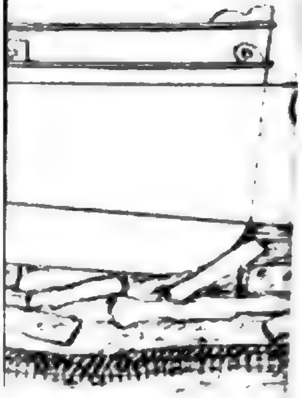

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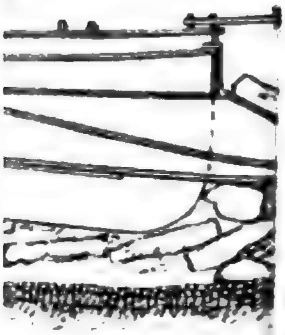

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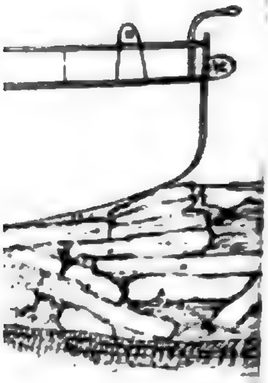

12

VI^th^ INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

3rd QUESTION.

MEANS FOR PREVENTING ICE BLOCKADES.

BY

C. F. CRAMER,
Secretary the Society for the development of steam navigation in the Netherlands.

THE HAGUE,
Printed by Belinfante Bros, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.
1894.

VIth International Inland Navigation Congress.

THE HAGUE, 1894.

MEANS FOR PREVENTING ICE BLOCKADES.

REPORT

upon the breaking of ice in the canals and rivers of the Netherlands by means of steamers specially fitted with ice-ploughs, furnished by the Society for the development of steam navigation in the Netherlands,

BY

C. F. CRAMER,

Secretary of the Society.

Since the application of steam to navigation and the construction of iron and steel vessels efforts have been made by means of steam-boats to break the ice over a considerable distance; the object in view however was not so much to keep the navigable way open or to clear away the ice as to reach a destination when some belated ship had been surprised by the frost. Generally steam-boats are employed to free vessels from the ice when they have been frozen up or wish to change their moorings. Although the results obtained by means of steam-boats that are not specially armed are comparatively feeble, it has however seldom happened that the end in view has not been attained. When the ice is too thick to be broken by the screw or paddle-wheels the vessel is driven at full speed against the ice. According to the power of the engine and the weight of the vessel, it will cut more or less into the ice. Two methods may be adopted, either the vessel is left in its ordinary condition and the bow is advanced straight against the ice, or the vessel is ballasted in such a manner that the bow will almost rise out of the water.

In the latter case the vessel advances upon and breaks the ice by its weight. It is impossible to say which of these two systems is the best, as it all depends upon the state of the vessel, the channel and the ice. Steam-boats with very sharp bows make a crack or gap in the ice of the same shape as the boat, and after penetrating into the ice about one third or half their length they are stuck fast. By reversing engines or by driving alternately ahead and astern and by turning the wheels first one way and then the other they may always be extricated.

It has frequently happened that having advanced upon the ice with the bows elevated they have gone so far that the help of another boat has been necessary to extricate them from their position. Experience has shown that suitably protected vessels, if the screw is at a certain depth below the surface and the engine is fitted with a reservoir into which the hot water resulting from condensation is collected, by which means the ice cannot touch the pumps, can navigate in the middle of floating ice without great danger.

Last winter when a sudden and severe frost occured and the Rhine was covered with ice within two or three days, steams-boats, and specially strong tugs, were at work both up and down stream for several days upon the Waal, where there was a large accumulation of ice. The ice cannot be broken by means of these boats without danger, except when it is not too thick and the channel admits of the ice thus broken floating to one side or the other or of being carried away by the current. The progress made during the frost is very small, for the boats, as we said above, cannot advance. But when the thaw sets in the results are far greater.

The effect on a bank of pack-ice or an ice-field produced by vessels not specially armed for the purpose is almost *nil*. Very heavy and strongly built boats obtain some results, but generally they are too slow. In 1861, the first year in which steam-boats were employed to break the ice at the governments expense, a comparatively small bank of pack-ice had formed in the Dutch Yssel, near Capelle, where the width was only 100 to 150 m. The steamer *Brouwershaven*, a strongly built tug, broke up this mass of pack-ice, but it took a whole day to do it and was favoured by the thaw.

During the winter of 1891—92 the Dutch Government ordered the removal of a bank of pack-ice which surrounded the piers of the bridge of Moerdijk; but the order was taken to mean: keep an open space around the piers of the bridge. With the help of six steamers, for the most part very strongly built, and a company of engineers, the order was carried out.

It was clearly proved that boats not specially armed for the purpose where not of much use. By taking a run of 100 or 200 m. the boats were driven against the ice at full speed, but only comparatively thin and regular ice was much affected; with ice, 30, 40 and 50 cm., as was here met with, the result was very small.

The boats were much damaged by working among the ice. The tug *Generaal van der Heijden* was sunk; the paddle-boat *Zeeland* was partly filled with water; the bows of the tug *Hoek van Holland* were stove in, and the

Hosanna had her screw broken. The paddle-boat *Wodan* and the screw-steamer *Rotterdam* alone were uninjured. The first of these according to an arrangement made with the Dutch Government was specially built for breaking ice. She is strongly built and armoured and is fitted with an engine of 500 horse power. The *Rotterdam* is a screw-boat of 250 horse-power which is made to slide upon the ice rather than cut into it.

In the reports which have been presented to the Congress upon this subject by the Waterstaat Engineers the *modus operandi* will no doubt be described, and it will be explained how it has been attempted with a certain amount of success to break the ice on different rivers and get rid of masses of pack-ice. By what we have said above we simply wish to show that by using ordinary steam-boats very indifferent results are obtained.

In 1861 the Government appointed a commission to study the means to be employed to clear away ice-fields and pack-ice. At the request of this commission Messrs. J. and K. SMIT, ship-builders at Kinderdijk, furnish the plans of an ice-breaker together with a report upon what could be done and what could not be done. This machine was specially intended for the clearing away of ice and was designed purely as an ice-breaker. The bottom was in the form of an elipse, the two ends were in the shape of an ice-plough, and the propulsion was effected by means of a wheel in the centre of the machine fixed in a sort of hollow. A drawing of this machine may be found in jason's periodical, 1873, p. 90.

The plans however were not carried into execution, although we consider it even now to be perfectly adopted to the end in view, provided it were modified and improved according to the experience acquired during the last few years. An unquestionable advantage consists in the two ice-ploughs, by the aid of which the efficacity of the machine is more than doubled. If by any chance any injury should be sustained by one of the two ice-ploughs the other is ready to take its place. When a channel that has been cut through the ice becomes once more obstructed, there is no need to go about, the machine is simply made to go astern.

To turn an ordinary steamer round or make it go astern when the ice is thick is always a matter of difficulty. If it is wished to scrape or cut the edge of an ice-field it is not necessary to turn round continually, but the boat is sent stern first by reversing the engines. When the machine has penetrated into an ice-field it can then break and crack the ice in every direction.

In 1881 the *Blauwe Ster* shipping company of Rotterdam fitted an ice-plough to a boat of 80 horsepower which answered the purpose for which it was intended. The same company then had an ice-plough made and fitted it to a screw-steamer of 150 horse-power. This apparatus was much more successful in thick-ice. The plough and the vessel were strengthened and improved according to the experience acquired, and it has now become a most useful machine and has rendered most efficient service.

The plough in question is much the same shape as the sock of the ploughs used in agriculture. It consists of two socks the sharp sides of which are joined together and form one point and the blades are fixed to the vessels head by two pegs. The two sides of the plough are strengthened by supports inside.

This plough is fitted to the vessel in a dry-dock or with the help of a crane. It is not only the construction of the plough buth more specially the arrangement of the vessel which render the services of the latter so effective.

No part of the vessel is straight; it is rounded aft on all sides as much as possible; the water-line is egg-shaped, so that the vessel cannot easily be gripped by the ice.

The greatest breadth of beam is further off than in most vessels, and the greatest weight is therefore in the stern. The head of the vessel is strengthened in the interior.

This form of construction has the double advantage of allowing the ice to flow past it without difficulty and of resisting the force which tends to drive the plough below the ice when it is at work. Moreover the vessel acquires the requisite position, the screw being well below water. The machine and the vessel have been built entirely from the plans of Mr. P. Meyer of Rotterdam.

In 1889 the shipping firm Van der Garden and Co., of Capelle on the Yssel, commissioned Messrs. J. and K. Smit, or Krimpen on the Lek, to build a screw tug called the *Krimpen a/d. Yssel* with an engine of 180 horse-power and fitted also with an ice-plough. The vessel is on the ordinary tug model and continually does duty as a tug. The plough has the following dimensions: length 10 m., width 4.50 m. and height 2.50 m.; it also has double walls which are connected above and below by pieces of flat-iron. The apparatus is therefore perfectly able to float. The vessel enters the plough from behind; with the help of a little ballast a good position is given to the vessel and the plough is riveted to it by means of bolts passed through holes provided for the purpose. These floating ploughs have incontestable advantages; they are easily moved about so that they may without difficulty be conducted to places where they may be needed during the winter.

They can be riveted to tugs without trouble and without the use of a dry-dock or powerful machinery, and from the experiments that have been made an hour is sufficient for the operation; also thanks to their ability to float the results are much more considerable. The more resistance the ice offers the more deeply the plough buries itself and the greater is the pressure.

These ice-ploughs may be made much larger than ordinary ploughs, because on account of their ability to float the boat is hardly at all hampered by their weight. The ice is broken by the centre of the plough and raised as it were, so that the pieces press against the inclined part of the plough and gradually assume a vertical position and finally fall back upon the ice alongside the channel.

In this manner the ice-ploughs leave behind them a channel that is almost entirely free from ice. At a race which took place by chance from Rotterdam to Kralingen through very thick ice between the ice-ploughs of the *Blauwe Ster* and the VAN DER GARDEN companies, they both gave proof of the same degree of power. Recently some other steam-boats have been fitted with similar floating ice-ploughs. among others the paddle-boat *Wodan*, which has become a most effective ice-breaker, and the screw-boats *Krimpen a/d Lek* and *Pernis*. The difference in the power of a boat without the ice-plough is beyond all comparison. We might mention as a striking proof of this that during the winter of 1890—91 the Waterstaat attempted with the aid of three powerful tugs, the paddle-boat *Maassluis* and the screw-boats *Colonel*. and *Dieu Donné*, to clear the ice from the Lek. These boats which were not fitted with any particular apparatus only advanced very slowly. A small screw-boat having at the most 180 horse-power and provided with a floating ice-plough advanced through the ice without difficulty, passed the steamers belonging to the State and worked on ahead of them. Without much difficulty it opened up a channel for a considerable distance and cracked the ice-field in many directions.

During the winters 1890—91 and 1891—92 the two ice-breakers mentioned above, *Krimpen a/d Lek* and *Ysploeg*, worked successfully in different places and under different circumstances.

In many places ice nearly 40 cm. thick was broken. Through ice 20 to 25 cm. thick a speed of 3 or 4 knots could be kept up. The *Krimpen a/d Lek* worked at Amsterdam during the winter of 1892—93 and without any interruption kept the Y open to navigation for 19 days, both in and round about the basin and in the Handelskade, generally returning to Ymuiden in the evening through the North Sea Canal. The screw-tug. *Ysploeg* in 1891 opened a channel from Rotterdam to Amsterdam, a distance ot about 73 km., and took only a day and a half to do it.

Besides these ice-ploughs there are now other ice-breakers in the Netherlands, that is to say those of the North Sea Canal. They belong to a company which undertakes to keep this canal open as well as the approaches to different commercial establishments in Amsterdam. The two ice-breakers, one large and the other small, were built at Stettin in 1893 on the model of the ice-breakers employed in North Germany in the mouths of various rivers. Their method of working is to mount upon the ice, which gives way under the weight of the vessel. They are built in such a manner that the after part is rather low in the water, while the bows rise to the surface or above it. They are provided with powerful engines, the largest of which is of 1100 horse-power. As these vessels work mainly by using their own weight they are naturally very strongly built. The De Maas ship-building yards at Delfshaven is at present building a similar machine at the expense of the State for the use of the Waterstaat. We are unable to pronounce any opinion on machines of this class, for they have not yet been put to any practical test. The winter of 1893—94 was neither very severe or long. To judge from the reports which we have received from Germany with regard to the working of these machines, as well as from the results obtained at Amsterdam, they are excellent ice-breakers, very suitable to work in the mouths of rivers and in rivers with sufficient current to carry away the broken ice. Their draught is considerable and prevents them working in a water-course that is less than 4 or 5 m. deep. They work just as well in canals, but the ice being broken in every direction is pushed violently forward for a distance of several metres in front of them and after the ice-breaker has passed floats into the channel that has been opened, a circumstance which interferes with the free movement of light inland navigation craft. Also by repeated rapid movements in the canal the broken ice is piled up against the banks.

The broken ice is a source of danger to navigation. When the ice-breakers advance against great masses of pack-ice which refuses to yield to their attack they run the risk of sliding on to the ice and remaining there. On the other hand these machines are most suitable for the breaking up of large ice-fields and for preventing the ice from packing. On account of their shape these ice-breakers will glide upon the ice when the packing commences and they therefore run no risk of being broken.

The companies that own tugs object to these machines, because they are of little use for other purposes when there is no ice, which is the case throughout the greater part of the year, and also on account of their excessive cost resulting from their special construction. By mentioning the objections made to these machines we do not however by any means wish to disapprove of them, for it is incontestable that they are extremely powerful. The largest of the two ice-breakers on the North Sea Canal possesses nearly 550 horse power more than the *Wodan*, which is the largest of the steamboats provided with ice-ploughs iu the Netherlands.

For the navigation of private waterways there is no question of procuring machines of this class for the reasons given above, and the shipping companies will content themselves with constructing ice-ploughs of 150 to 200 horse-power the price of which, 2000 to 3000 florins, will be within their reach. Moreover, whatever the build may be, every steamer can be fitted with an ice-plough without any change being made in the vessel itself, and these vessels lose nothing of their value or utility.

It is also essential to take into account the variability of winters and consequently the short time that these ice-ploughs can be used. This is clearly shown from the following table which gives the number of days during which the waterway from Amsterdam to Schiedam (Netherlands) has been covered with ice between 1870 and 1894.

1870–71 from 21st December to 19 February	60 days.
1871–72	0 »
1872–73	0 »
1873–74	0 »
1874–75 from 29th December to 4th January	7 »
1875–76 » 10th January to 22nd January	13 »
1876–77	0 »

1877—78		0 days
1878—79	from 10th January to 8th February	30 "
1879—80	" 4th December to 3rd January and from 19th January to 9th February	53 "
1880—81	" 14th January to 5th February	23 "
1881—82		0 "
1882—83		0 "
1883—84		0 "
1884—85		0 "
1885—86		0 "
1886—87	from 17th January to 24th January	8 "
1887—88	" 28th February to 7th March	8 "
1888—89		0 "
1889—90		0 "
1890—91	from 1 December to 7th February	67 "
1891—92		0 "
1892—93	from 3 January to 31 January	28 "
1893—94	" 4 January to 17 January (1)	13 "

Properly speaking it was only after the severe winter of 1890—91 that greater efforts were made in the Netherlands to improve ice-breaking machines; still, as we have said above, only the ship-owners paid any attention to the subject and they had ice-ploughs made which could be adopted to the tugs that were already in existence.

We much regret our inability to give further information on this subjet and must refer to the experiments made with these machines by members of our Society. In describing the ice-plough we have already given some details with respect to the work done by these machines and we may therefore refer to the almost unanimous opinion, founded on experience, upon what can and what cannot be accomplished by the ice-plough.

We refer only to the rivers and canals of the Netherlands and we will occupy ourselves with the different navigable ways successively as well as with the state of te ice.

1. The canals employed for navigation, that are not less than 2.50 m. deep, can always be kept open by means of the ice-plough. With a very hard frost the ice does not become more than 40 to 50 cm. thick. In ship canals a channel of sufficient width can be opened up very rapidly by an ice plough adopted to a screw steamer of 500 horse-power which will work during a frost which will form ice nearly 15 cm. thick in the space of 24 hours. During a thaw ice 25 cm. thick can be broken by a steamer of 150 horse-power at the rate of 3 to 4 knots an hour. Shallow canals are more difficult to free from ice when the ice is thick or the frost very severe, because a boat of sufficient power cannot be employed. For these waterways it would be necessary when it is desired to keep the channel free to begin in good time and by repeatedly sending boats through to prevent the ice from becoming strong.

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(1) This table has been compiled from data furnished at Schiedam. According to an ancient custom no list is issued in winter of the quantities of gin, until the boatman of Amsterdam has had to stop work on account of the ice, whatever the quantity of gin may be that has been bartered.

2. In sea-ports and the mouths of rivers where there is not much tide, ice-ploughs may be employed with equal success. What we have said above with respect to the breaking of ice in canals is equally applicable to these waterways.

3. By means of powerful ice-ploughs deep rivers with a fairly rapid current may be opened up to navigation, provided large ice-packs have not been formed. If such rivers have not a depth of more than about 2 m. the only way is to break the ice by means of powerfull paddle-boats.

This depth does not allow of the requisite power being produced by one or more screws. In rivers with running water any sort of ice-breaker may be employed indifferently, because the ice once broken is carried off by the current. If the river is everywhere obstructed with ice after a severe frost and the broken pieces are piled together, the most powerful ice-breakers will be of no use. It is only during a slight frost or during a thaw, when the mass is not so compact that there is any chance of clearing it away.

If there is difficulty in clearing away ice in this state, it goes without saying that with the resources at our disposal we can do absolutely nothing to break up ice-fields and ice-packs of a certain thickness. It is only during a thaw that any result can be obtained; the danger however of being crushed is very great, because the general breaking up of the ice very often occurs quite suddenly. On the other hand we can work with success on rivers where it is a question of ensuring the flow of water in a confined bed, in order to facilitate the free passage of ice, and where between the ebb and flow of the tide the ice remains temporarily immobile and might become very strong. Large masses of floating ice are thus broken up with great ease. In every case it is essential to begin in good time and in this way much labour will be spared. With a large enough plant if will in our opinion be possible under normal conditions to float away the ice on the lower parts of rivers as well as in their embouchures, and it is therefore necessary to place ice-breakers in dangerous places that they may break up the large flocs and ice-fields, when the ice that has been set free begins to float away more slowly as it rubs against the shoals, groins or along the bank. By the continual displacement of the ice it will finally be carried away. By freeing the lower part of rivers the regular flow of ice up stream will be considerably facilitated.

Ice-ploughs driven by screw-steamers will be able to do what is necessary; besides the effective way in which they break the ice they run less risk of being caught in the ice. They throw back the broken fragments on the ice that is still intact, so that there is eventually an open space through the frozen surface. Our ships are powerless to struggle against ice floating down a river especially when the general breaking up of the ice takes place. To navigate under these circumstances with success, vessels of a special build would be necessary, in order that the ice in movement might nowhere meet with a flat surface. A build must be chosen which will cause the ice to be pushed down at a certain angle or the vessel to rise. A boat thus strongly built escapes the danger of being crushed by the ice that is raised above the surface. The ice-breakers of the North Sea Canal are constructed on these lines. In order to make our explanations clearer we subjoin five diagrams of the screw-tug *Pernis* which has been recently built. It has 240 horse-power and is armed with a floating and adjustable ice-plough.

N°. 1. An ice-plough in course of construction which is fitted to the stern of the tug.

N°. 2. The same complete, viewed from behind.

N°. 3. The same complete, viewed from in front.

N°. 4. The same fitted to the tug while at anchor.

N°. 5. The same fitted to the tug and ready for use.

Also a drawing of the screw-steamer *IJsploeg* in dry-dock.

The experience acquired last winter has suggested certain improvements in ice-ploughs. When it is wished to keep a channel open in a canal, or if it is wished to break up the ice which obstructs it, the lower part of the plough must have a horizontal projection against which the broken ice may press and be more easily thrown on one side. Experience has also shown that on account of the flatness of their shape ice-ploughs may become fixed in the ice. To avoid this the lower part of the plough is made obluse-angled.

To thoughtlessly drive the plough against a mass of very strong ice generally only damages the machine. In many cases it is preferable to simply cut the ice. Here again experience will be the best guide and in the course of time the efficacity of these machines will probably become much greater. From a commercial point of view it has frequently been proved that ice-breakers present many advantages, especially for the navigation of sea-going ships. If has been possible to render ports navigable so that vessels can arrive and depart and be loaded and unloaded even during a severe frost. For inland navigation the advantages are small, but this should especially be attributed to the small number of ice-breakers in existence. When the principal navigable way has been opened up directly after the thaw there is no advantage gained if the secondary waterways remain frozen for several days and navigation on the canals in towns is stopped. Moreover there are various regulations in force in the provinces and municipalities of the Netherlands by virtue of which the breaking of the ice is forbidden and it is not allowed to open the bridges until the thaw has commenced.

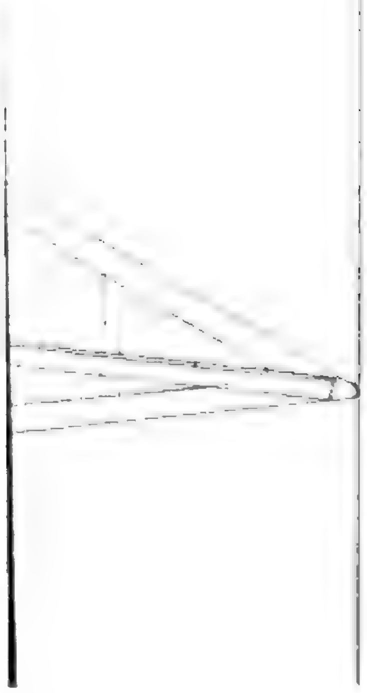
The Netherland Government might generally favour the construction of ice-breakers by employing when necessary vessels which are used exclusively for this purpose, or which are provided with special apparatus.

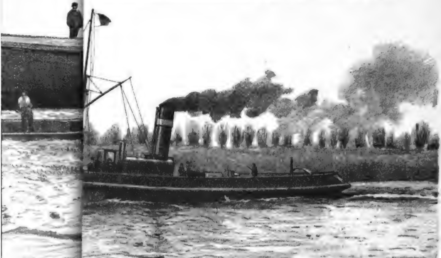
The *Stoomvaart-belangen* company, as well as private industry and navigation have been obliged to give their attention to this question.

The company hopes that it has helped to solve this problem, which is a matter of the highest importance for many countries, but especially for the Netherlands.

LOE

.OEG.”





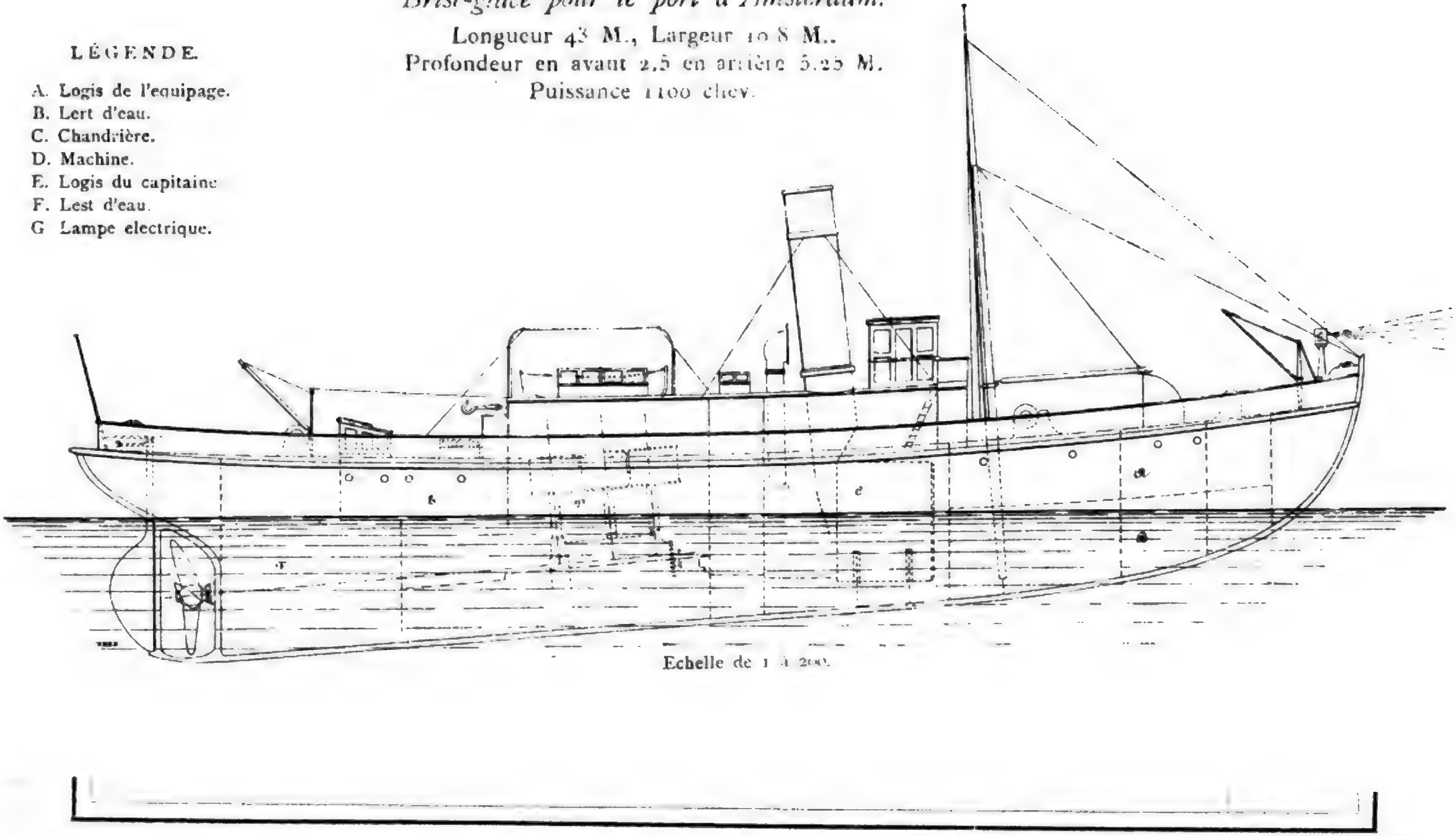
Google

Brise-glace pour le port d'Amsterdam.

Longueur 43 M., Largeur 10.8 M..
Profondeur en avant 2,5 en arrière 5.25 M.
Puissance 1100 chev.

LÉGENDE.

A. Logis de l'equipage.
B. Lert d'eau.
C. Chandrière.
D. Machine.
E. Logis du capitaine
F. Lest d'eau.
G Lampe electrique.



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13

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

4th QUESTION.

Traction and propulsion on Canals, canalised rivers and on free-current rivers

BY

J. HIRSCH AND M. B DE MAS
Ingénieurs en chef des Ponts et Chaussées.

THE HAGUE,
Printed by Belinfante Bros, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.
1894.

VIth International Inland Navigation Congress.

THE HAGUE, 1894.

Traction and propulsion on canals, canalised rivers and open rivers.

BY

J. HIRSCH and M. B. DE MAS,
Ingénieurs en Chef des Ponts et Chaussées.

SUMMARY AND DIVISION.

The proposed programme is divided as follows:

> „Progress realised since the last Congress in the application of different systems for the traction and propulsion of boats. New systems since invented or adopted. Influence of the form of boats, and the condition of their surface on resistance to traction. Speed necessary and attainable for carrying-boats towing in train."

This programme comprises two entirely distinct ideas.

In the first place the study of methods of traction and propulsion of boats, and in the second place an examination as to the form of boats, and the influence, which the form and the condition of the wet surface may exercise on resistance to traction.

The present report is divided into two parts, corresponding to these two orders of ideas. The first part has been edited by M. J. Hirsch, and the second by M. M. B. de Mas.

At the end of these reports will be found in the form of Annexes a collection of various information, which we think will be of interest to members of the Congress. These particulars have been supplied to us as the results of an inquiry made by Engineers in navigation service, and by Directors and Managers of transport undertakings.

We thank our obliging correspondents for the willingness with which they have replied to the questions we took the liberty of asking them.

It will be understood that we have been obliged to limit our studies to the system of French Waterways; and we leave to our fellow-workers abroad the task of examining these questions in so far as they concern their own countries.

Paris, April the 26th 1894.

M. B. DE MAS. J. HIRSCH.

PART I.

Methods of traction and propulsion.

BY

J. HIRSCH,

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The French system of navigable waterways is of a special character, resulting from the mountainous nature of the country. The large currents of traffic are not, as in other countries, limited to important and extensive valleys. The majority are established from one basin to another and connected by canals divided into reaches. These artificial ways have been for the most part resolved into one uniform model, which allows of the passage of a boat adopted as a type, viz. the Flemish *péniche*.

The rivers form a prolongation of the canals; they are traversed by boats which navigate the canals, and this is most frequently their essential service. But besides this general traffic they possess a local navigation served by plant, which is in no way subjected to the model of the canals.

The result is that the methods of navigation employed are not the same on the canals as on the rivers. For the sake of clearness it will be useful to examine separately what occurs on the canals as well as what occurs on the rivers. The canal navigation presents a very pronounced character of similarity and uniformity. It is with this part of our programme that we will commence.

TRACTION ON CANALS.

With regard to traction on canals the general position has not perceptibly changed since the last Congress. The particulars furnished in the remarkable reports of MM. Derome and Lasmolles still represent the present state of things. We will complete them (see Annex V) by a few particulars concerning navigation on the canals of central France.

Apart from a few exceptional cases the boats always travel singly, the locks being too small and too near to each other to allow of navigation in convoys.

In proportion as the work of improving the canals progresses, as they are reduced to the regulation model and as the tonnage of the boats consequently increases, it is seen that towage by manual labour has a tendency to decrease and to give place to traction by horses.

Mechanical traction, which it was thought would become the solution of the question of the economical working of canals, has remained, except in one special case, in the same condition as formerly. This mode of towage encounters obstacles of various kinds, technical, economical and social, to which we will refer later on, and which have up to the present paralysed all efforts made to resolve this serious problem.

Carrying-boats.

A few carrying-boats, worked by steam, navigate our canals; they are propelled by paddle-wheels fixed at the stern, and in such manner as not to exceed the width of the regulation model. This mode of transport does not develope itself to any extent.

Funicular towage.

On the proposition of the 2nd Section, the fifth Congress expressed a wish that experiments in funicular towage should be continued; it considered that if the difficulties, which had been encountered in the experience of this mode of traction, could be obviated, it would constitute a practical solution of the question of traction on canals of large traffic.

The system of funicular towage, conceived by Mr. Maurice Levy and applied by time on the St. Maurice canal, near Paris, has been completely described in the publications of preceding Congresses on navigation, and has given rise to profound discussion in these Congresses. For the moment, the subject may be considered to be exhausted, and it is advisable before returning to it, to wait until the practical application of this ingenious system has given some decisive results. These results will not be long delayed; in fact the Administration has decided, that the plant shall be established on the canal from the Aisne to the Marne in the Mont de Billy tunnel, near Rheims. The section to be served comprises a length of 2300 metres, which corresponds to about five kilometres of cable. It will probably be finished in the course of this year and put in operation before next winter.

This great practical experiment will be followed with lively interest by all who are engaged in matters connected with inland navigation.

Magnetic towage.

The application on canals of the principle of towing which has succeeded so well on rivers has often been attempted. At first sight the thing appears easy. A chain laid at the bottom of the water is seized by a snatch-block carried by the tow-boat and worked by any sort of motor. Progression of the vessel is the result. The power to be developed is small; therefore the motor may be of little weight and the chain need not be of great strength, conditions eminently favourable, when it is a question of boats travelling alone.

In working-trials serious practical difficulties have been met with, amongst the gravest of them being the following:

The difficulty of assuring, without too cumbrous apparatus, adherence between the chain and the snatch-block, and supposing this adherence established, the difficulty of loosing the chain. This led up to the idea of using two chains, one for going and another for returning, a complication which seemed unacceptable.

There was also a difficulty in obtaining small motors to work with security and economy.

We leave aside the question of the passage through locks, which seems to offer several acceptable solutions.

Perhaps, by the employment of electricity, today so general, one might say so common, these obstacles may be triumphed over. Adherence might be effected by electrically magnetizing the snatch-block, as was done by M. DE BOVET on the tow-boat *Ampère*, of which we will give a description later on. Such a system allows of the chain being thrown with the greatest of ease. The electric current, which magnetizes the snatch-block, would feed at the same time a dynamo which would set the snatch-block in motion. All this mechanism, which is extremely simple and incomparably light, may, if elementary precautions be taken, be managed by any boatman. With the low rate of speed used on canals the flow of the current on a continuous conductor would be effected with great certainty. Finally, the production of a current of several horsepower would most frequently be obtained in a very economical way.

The system appears from all points of view very enticing, and it is advisable to encourage experiments made in this direction. Many engineers have taken up the question; M. DE BOVET especially is making it the object of serious study. Let us hope that he will have something interesting to communicate to us at the Congress at The Hague.

Electric towage on the Burgundy Canal (1).

Electric towage has been applied on the dividing reach of the Burgundy canal. This, it is true, is only one particular case, but the success has been so complete as to encourage the greatest hopes of a more general extension of the system.

At the time of the last Congress this system of towage was merely a project; now that practical experience has been obtained, followed for several months, and crowned with complete success, the study of it has quite another interest. We shall be allowed therefore to describe it in some detail.

The reach of the Burgundy canal is 6 kilometres in length, of which 3300 metres is tunnel. The width of the waterway is 6.10 in the tunnel and 7 metres between the banks in the open. The depth of water varies from 2.25 m. to 2.40 m., the latter being the most usual. In the reach the canal has only sufficient width for one boat, when therefore boats are at travelling in train these are despatched alternately in one direction and the other.

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(1) Communication from M. GALLIOT, Ingénieur des Ponts et Chaussées à Dijon.

From 1867 to 1893 these trains were towed by steamboats worked by a chain of 6 kilogrammes to the metre. These boats were provided with machines fed by boilers which were supplied by reservoirs of boiling water on the Lamm-Francq system. In the last few years 200,000 tons have been annually towed in this way at a cost of 16,000 to 20,000 francs including all amortisation. The system worked well; and the only difficulty was that it was dear, the cost of maintenance especially being high.

In 1888 the old tow-boats being no longer serviceable, a better solution of the difficulty was sought for by utilising the natural forces of the waterfall at the canal locks.

The study of the question resulted in the conviction that at least 40 or 50 thousand cubic metres of water were available each day for the two locks which terminated the reach.

The ground was studied and it was decided to create a fall of 7 metres on the Seine side and one of 8 metres on the side of the Saône, and calculations were based on a daily discharge of 30,000 cubic metres of water, of which 18,000 cubic metres came from the water-shed of the Seine at Pouilly, and 12000 cubic metres from the water-shed of the Saône at Escommes. Under these conditions the force of the water is at Pouilly 20 horse-power, and at Escommes 15 horse-power, together thus 35 horse-power.

The water-tank of the turbine is of cast-iron, and covers the regulator, from which it is separated by a sluice-door of bronze in the shape of a circular sector. The regulator covers a little less than half the circumference of the receiver. When stopping, the bronze sector closes the distributing valves. As soon as the turbine begins to work it regulates itself the admission of water as we shall explain further on.

The turbines of Pouilly and of Escommes are both constructed on the same model. They are on the Girard system with free deviation.

The vertical axis of the turbine reaches to the floor of the engine-room, and terminates in a mitre-wheel corresponding with another mitre-wheel on a horizontal shaft, which has its support fixed on the floor. This horizontal shaft carries a fly-wheel which is connected by a belt with the generating dynamo.

The generators are on the Grammesystem and are of a superior type.

The generator at Pouilly is constructed to produce a normal power of 30 amperes with 370 volts. The inductors are covered with wire of $\frac{23}{10}$ millimetres and the induct with wire of $\frac{9\cdot 4}{10}$ milimetres. The normal rate is 900 revolutions.

The generator at Escommes furnishes 30 amperes with 280 volts. The diameter of the wire of the inductor is $\frac{23}{10}$ and that of the wire of the induct $\frac{9}{10}$ and the normal speed is 1250 revolutions.

The two generators are joined in tension. A conducting wire connects the two opposite poles of the machines, and from each of the two other poles a conducting wire runs both on the right and on the left side of, and parallel to the first wire.

It is on these two last wires that the electric current is communicated to the receiver by means of friction.

Under these conditions when the water-wheel is moving at its normal rate the total tension is 280 + 370 = 650 volts. The resulting current is 30 amperes. Generally this result is not reached, but it varies between 12 and 25 amperes according to the cargo towed.

The conducting line, which is a telegraph wire of 8 millimetres diameter gives a resistance of less than 4 ohms on the circuit of about 10 kilometres traversed by the electricity.

The loss of power is therefore 100 volts for a current of 25 amperes, and under these conditions the receiver receives the current with about 550 volts, and thus absorbs 550 × 25 = 13750 Watts, or a total force equal to 18⅔ horse-power.

It is extremely rare that such a high power is required.

The mode of connection above described, presents the advantage that the length of the conductor traversed by the current remains always the same on whatever part of its journey the tow-boat may be.

The only difficulty with this mode of connection results from the stimulus lost. It was necessary to employ this mode of stimulus in order to be able to use accumulators.

When a boat is put in motion every generator tends to invert the polarity of the one next to it. To obviate this difficulty it suffices to admit the current slowly. This is effected by the aid of a powerful unmooring rhéostat giving a resistance of 180 ohms.

The regulators of the turbines form an interesting part of the construction. It has been shown that the more or less complete closing of the distributer is effected by means of a bronze sector which slides over the openings of the distributer.

This sector may be manœuvred by a wheel which is worked by hand; but it may be likewise guided by a very ingenious system of automatic regulation.

To one of the shafts of the turbine are attached two cog-wheels corresponding with another cog which is in relation with the bronze sector. If one of these wheels be put into gear with the friction-clutch of the turbine, it is evident that the sector will turn in one direction or the other.

The coupling is effected by electro-magnetic adherence, according to the system conceived by M. de Bovet. The electricity is supplied by a local pile. The current is conducted into one of the cog-wheels, or interrupted at will by the aid of a commutator, the condition of which is dependent on the current which traverses the principal line.

For this purpose a solenoid is applied to the inductors of the generators.

The solenoid is double and its two armatures are suspended at the ends of the beam of a balance and in such manner that one armature has its centre above the centre of the corresponding solenoid, while the other has its centre below it. When the current passes the solenoids attract their armatures and the balance sinks on one side: as one of the arms of the balance is surcharged this gives the equilibrium for a certain voltage.

If, in working, the voltage becomes too weak, the balance will incline in the direction of the surcharge, and to the other side if its voltage becomes too strong.

The beam of the balance carries at each of its extremities metal forks, which plunge into the cup of a quicksilver commutator when the inclination of the beam is sufficient, thus establishing communication between the pile and the friction-clutches.

This system is excellent; the regulator is easy to manage and very sensitive. Unless under exceptional circumstances it does not allow of a deviation of voltage of more than 5 to 10 %. The normal voltage is easily regulated by surcharging more or less the armatures.

The list of organs required for the distribution has nothing special in it. It contains a stimulus rhéostat, an ampere-meter, a volt-meter, a lightning-conductor, silent-apparatus, both automatic and manual, a tachymeter etc., accessories which are to be found in every electric establishment.

The system is completed by a battery of accumulators, which is composed of 250 elements of the type of the *Société pour le travail électrique des métaux*, each consisting of 4 negatives and 5 positives of 215 by 105. In ordinary circumstances the charge should be a current of 10 amperes and the discharge should give 15 amperes.

These elements are joined in series, so that the electro-motive power of the battery varies about 2 × 250 = 500 volts. In charging it will easily support 2.2 × 250 = 550 volts, and in the discharge the voltage may without inconvenience fall as low as 1.8 × 250 = 450 volts.

The battery is connected with the conducting line parallel to the receiver. The connection is continuous, so that the accumulators act as fly-wheels. The battery working alone is sufficient for two journeys in each direction.

It is established in the cellar of the house which serves as residence for the chief towage engineer.

The conducting line is composed of three bronze telegraph wires of 8 millimetres diameter. The metal presents a mechanical resistance of 45 kilogrammes per square millimetre and its conducting power is 97 % of the pure copper.

The total circuit traversed by the current being about 12000 metres the resistance is 3.9 ω.

When working at full power, i. e. 30 amperes with 650 volts, the line absorbs a force of $R\,I^2 = 3.9 \times 30^2 = 3510$ ω

The development is therefore $\frac{650 \times 30 - 3510}{650 \times 30} = 82\ {}^0/_0$.

When working at its most usual speed, that is with 15 amperes and 650 volts, the development is $\frac{650 \times 15 - 3.9 \times 15^2}{650 \times 15} = 90\ {}^0/_0$.

The three wires of the line are so disposed as to form the three edges of a prism 0.10 m. in height with a base of 0.20 m. by 0.30 m., the two edges of the base being formed by the wires on which the current travels.

For keeping the wires in the required position isolators of a special form are used.

Three isolators are supported on a grooved iron rod 0.25 m. or 0.35 m. in length. The return wire not being used for taking the current is simply placed in the notch of the isolator and tied there.

The two wires which serve for taking the current are suspended underneath by means of copper wire hoops.

The isolator-bearers are at a distance of 20 metres from each other.

The line so constituted forms an open circuit. To complete the circuit it is only necessary to place the two outer wires in contact with the poles of the receiver.

This is effected by means of two trolleys carried by the boat. As in American tramways, these trolleys are composed of two long articulated poles, which are followed on their whole length by a flexible conductor issuing from the poles of the receiver and terminating in a roller which communicates electrically with the conductor and follows it constantly along the line.

The arms of the trolleys are 7.50 m. long and are composed of a tin tube of 4 m., in which is hafted a bamboo-rod of about 3 m. On this so constituted pole are fixed supporters in V form, consisting of thin tubes, and the whole is strengthened by steel wires. The poles are maintained in a vertical position by springs.

At the end of these poles are the pulleys which receive the current. The bearings are articulated in such a manner that they lend themselves to any lateral movements which the boat may make. At the end of the arms of the trolley the conductors cross a dividing table and join the two poles of the receiver. This is a GRAMME machine of superior type, arranged in a series of electrical tension in wire of ${}^{44}/_{10}$ for the electros and ${}^{22}/_{10}$ for the roller.

The resistance of the inductors is 6.1 ω and that of the inducts 0.55 ω.

On trials at which 900 revolutions were made with 30 amperes and 550 volts it gave 19 horse-power with the brake on.

The development was therefore 85 ${}^0/_0$.

The machine receives a greater or less force in proportion to the trains it has to tow. It works well with different cargoes in tow, and is remarkably free from sparks. Its table contains nothing special unless it is its unmooring-rhéostat of 180 ohms.

The receiver is connected with the traction-wheel by a belt. The pulley of the dynamo has a diameter of 0.30 m. and a fly-wheel of 1.80 m.

The wheel-axle governs the cylindrical wheel by a series of cog-wheels which are geared for two rates of speed. The normal rate is 20 or 40 revolutions per minute according to the wheels used. The rate of progression of the boat is then 0.70 m. or 1.40 m. Of course this speed varies in a large degree according to the cargo towed.

The boat is 15 m. long, 3.20 m. wide and 1.20 m. deep. The draft of water is 0.45 m. The fore and after parts are covered with fluted sheet-iron, and the central part for a length of 8 m. carries a cabin built of thin sheet-iron to protect the apparatus and the staff from wind and weather.

In order to obviate the danger of the chain bespattering the boat, it is entirely enveloped in a sheath, formed underneath like a *U*, and a movable half-cylinder of thin sheet-iron on its upper part. The tow-boat is provided with two rudders which are worked together by means of mechanical transmission. The chain enters and leaves the boat by two holes similar to those ordinarily used on river steamboats.

When in the tunnel the boat is lighted by electricity, as also are the cabins.

The above described arrangements were projected by M. GALLIOT, Ingénieur des Ponts et Chaussées under the direction of M. FONTAINE, Chief Engineer of the Burgundy Canal. They were approved by the Minister of Public Works on the 8th of February 1893. The work was immediately commenced and was finished on the 15th of July following.

The local direction was entrusted to the conductor M. VAILLARD.

The total cost of the establishment of the system was 139,000 francs.

Experimental trials were made during one month, viz. from July the 15th to August the 15th and since this date no other system than the electrical has been employed for towage.

The working of the system is carried on in the most simple manner.

From the present time, after the exceptional summer of 1893 and the rather cold winter which followed, during which the service was continued without break, we have a right to say that experience has shown that the system of POUILLY has justified all hopes that were formed of it.

TRACTION AND PROPULSION ON RIVERS.

If the conditions of navigation on canals are nearly everywhere the same, the case is entirely different on rivers. Each waterway has, so to speak, its own physiognomy, characterised by its slope, its water-power, the dimensions of its bed, the works that have been established on it etc. This physiognomy frequently differs very much on various points of the same river, and it changes with the seasons. Hence an almost infinite variety in methods of navigation.

Certain rivers of secondary importance are managed in the same way as the canals of which they are a continuation, and their plant is on the same model. From the point of view of navigation it is as well to place them in the category of canals proper.

The large waterways, which are the only ones we have to consider here, are divided in two classes; those of which the water flows freely, and those which are canalised by flood-gates. In the latter case the flood-gates are generally of large dimensions.

These waterways have to serve as well for the local traffic, which does not leave the valley, as for the general traffic brought to them by the artificial ways in connection with them. They are thus used by canal boats as well as by other craft especially fitted to local conditions.

As regards canal craft, steam boats suffice for themselves, but, apart from this particular case, all other boats have to be moved by some exterior power. Going down stream they often drift with the tide, while in certain cases single boats or small convoys are drawn by horses.

Navigation in Convoys.

A practice which is becoming more and more general is the employment of mechanical power for drawing more or less heavy convoys, in which may figure canal boats as well as local craft.

Mechanical traction is effected in various ways.

The motor may take its point of support directly from the bed of the river (*grappins*), from an submerged chain (*toueurs*), or from the surrounding water (*tugs*).

Grappins are still in use on the Rhône. They are powerful steam-vessels with paddle-wheels which serve for propulsion when descending the river. They carry, in addition, a large central wheel worked from the steam-engine, and provided with solid teeth. In ascending, this wheel rests on the bottom of the river and the teeth bite into the gravel which forms the bed. This method of traction is peculiarly adapted to the nature of the Rhône and to the conditions of its traffic.

Tugs are often built with paddle-wheels but more frequently with screws. Important progress has been made of late years in the construction of these boats, their propellers and their engines.

Towage by chain (*toueurs*) is, as far as we are aware, the only system at the present day in general use.

The chain is rolled many times on two parallel fluted drums, which turn with equal speed under the action of a steam engine.

Tugs have great freedom of movement, go quickly or slowly, turn in a small circle, move perpendicularly to the banks etc. They have other considerable advantages, such as freedom to discuss conditions and prices for services they render to navigation and thus make the most of any favourable circumstances which may arise. When the strength of the current is rather great, they work in ascending, under unfavourable conditions.

Towage on chain allows of less liberty of motion. The capital required for its first establishment including the price of the chain is much greater. But when the current is rather strong, the machine in ascending uses its motive power much more economically than the tug. On the descent, on the other hand, the towage on chain is less profitable, sometimes impossible. With the present system of adherence by means of two parallel drums the operation of throwing the chain is long and laborious. It is reduced as much as possible by various artifices. Sometimes the chain is composed of short sections, which are so mounted as to be easily disconnected and rejoined to allow of their being exchanged. Other companies prefer the *traquage* system, according to which each boat traverses only one section of the way, and exchanges its convoy with the boat of the next section.

The laying of a chain constitutes a monopoly, an appropriation of the public domain for the benefit of one party, and it can therefore only be allowed by virtue of a concession issued by the administrative authority, and this concession necessarily implies conditions which may become very burdensome, especially as regards tariffs. Here we have some extremely delicate questions, which it would be out of our province to enter upon here, but of which the solution may exercise a decisive influence on the prosperity of the enterprise.

The study of systems of tugging and towing has been made at the Paris Congress in such a complete way and with so much authority and competence, that we do not think it would serve any useful purpose to continue it here.

In the Annexes II and III will be found some supplementary particulars concerning local applications of mechanical traction.

Towage by magnetic adherence.

Since the last Congress important progress has been realised. The magnetic adherence tow boat which was then only projected has now entered into regular service.

It seems therefore that the time has arrived to give a description of this remarkable apparatus (a).

At the Congress of Paris, MM. Molinos and de Bovet have examined the conditions with which a well organised service of towage should comply.

(a) This description is compiled from particulars kindly furnished by M de Bovet, Director of the C^ie du touage de la Basse-Seine et de l'Oise.

In place of the ordinary tow boats attached to their chain, it would be advisable, according to these engineers, to subsititute toueur-tugs, that is to say, tug-boats with screws or wheels, and supplied with a towing apparatus which would only be used in ascending. The apparatus should be very simple, not liable to damage the chain, and permitting of its being thrown into the water without difficulty at any point of the journey.

The relay service should be done away with and tow-boats ascending should conduct their trains to their destination without *traquage*. Descending, they would function as tugs. The service would thus be double and would consequently gain in regularity, in speed, in power for traffic, and in economy. In order to comply with these conditions it was necessary to find an effective system of traction working with a very short chain on the towing apparatus. To obtain the necessary adherence, M de Bovet has adopted the ingenious idea of magnetising a single drawing snatch-block.

The snatch-bloch (see Table I, figs. 5 and 6) consists of two cast-steel plates *a* and *l* carefully adjusted and connected by bronze bolts *g*. They form between them a circular cavity partially filled by the coiled conducting wires *k*.

The bottom of the cavity is closed by a bronzed ring *e* with caoutchouc joints, which prevents the roll of wire being moistened by the water.

The electric current taken on two isolated rings penetrates in the pulley by an opening *l* made in its axis *m*.

It should not be forgotten that at the trials an old chain which had been reduced by use to a weight of about nine kilogrammes to the metre showed when at rest on the trial-snatch-block and surrounding only three quarters of its circumference an adherence of 6000 to 6500 kilogrammes.

The wetting of the chain by ordinary water or with soapy water does not cause a loss of more than about 10 $^0/_0$ of the carrying power.

Even when very much twisted and excessively oiled a new chain carried more than 4000 kilogrammes. With the old chain an adherence of 6000 kilogrammes was obtained by means of a current corresponding to only 3 horse-power. The force necessary to detach the block is at most 300 kilogrammes for a new chain with a maximum current.

The knowledge of this force has led to the discovery of means of ensuring the detachment, that is the separation of the snatch-block and the links of the chain.

The edges *c*, *d* of the cavity being exposed to wear are affixed in such a manner that they may be easily and speedily replaced.

Such is the principal organ employed in towage by magnetic adhesion.

The construction of the tow-boat was undertaken by M. Henri Sâtre, with the exception of the installation of the electric part which is due to Messrs. Sautter, Harlé & Co. Its length is 33 metres, its internal width is 5 metres, the depth 2.70 m. and the draught of water when the boat is working is 1.90 m.

The engine of the *Pilon*, type can by means of two friction-clutches put the screw in working with a development of 150 horse-power for 150 revolutions, or set in motion the towing apparatus by means of cog-wheels with a power of 60 to 80 horses and 90 revolutions when travelling on the chain.

At the after part of the boat are placed two boilers, each of 150 horse-power. There are, just as in the towing boats, two rudders with commanding wheels *G* and *G′*. The first one has, when in repose, no tendency to turn when the boat is using the screw. The form of the hull affords to this tow-boat a satisfactory action as a tug.

Two water-ballast compartments, *W W*, can by means of a pump remove a certain quantity of water, so as to deepen the after-part when travelling with the screw and to reestablish the level when towing.

Fore and aft the chain passes through the holes *F F′*, and then between the vertical rollers *E E′*. It then leaves its guide *D*, whence it goes to surround three-quarters of the towage-snatch-block A (figs. 2 and 5), where its entrance and departure are governed by the rollers *B B′*, which are symmetrically disposed and mounted on pedestals, so that the chain may be easily placed and when necessary thrown into the water. We will only observe that the magnetic metal roller *B′* assists, together with the hard-metal and non-magnetic pin *H*, in the detachment of the chain. On the fore-part the other pin *H*, symmetrical with the above, assists the detachment of the chain, but only when the motion is backwards.

Between the egress of the chain *D′* and the mouth *F′* there is a well, large enough to receive 20 to 25 m. of chain, which naturally drops into it down an inclined plane.

When a tow-boat approaches a curve the chain, in consequence of the strain on it, has a tendency to approach the centre and to place itself in a more direct line; consequently there is a slackness of the chain at the place where the tow-boat is. The question is, therefore, to keep this slackness on board and to give it out only gradually during the passing of the curve. This object is attained by the brake, *M*, which can be regulated according to necessity; it lets out less of the chain (before the passing of the curve), or more (during the passing of the curve) than has been taken in in front. In the absence of this brake, the slackness, on account of its returning to the water at the same time as it was produced, would not be available when again required, as the ascending tow-boat would leave the chain closer to the convex bank than it was before.

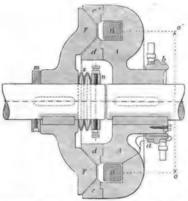
P is a magnetised snatch-block with a revolving speed equal to the speed of the towage-snatch-block and developes in its revolution a power of 200 to 300 kilogrammes; on this snatch-block the detachment of the chain is effected naturally by its fall into the well.

The apparatus for letting it drop into the well is shown on fig. 7.

Two rollers, one on each side of the magnetised snatch-block, compel the chain to make its contact on a length sufficient for the magnetic adherence.

The pivots of these rollers are vertical pins, which are surrounded by strong traction springs, so that when the tension of the chain is strong at the side where the links emerge, the springs give way and the two rollers rise, which prevents an abnormal pressure on the supports.

Friction-clutch for magnetic adherence, DE BOVET's system.



When the chain is straight it only touches the magnetised snatch-block in one point, but it is in this case that the action of the pulley is superfluous, so that under any circumstances the detachment *H* does not work, or scarcely so. This entrance snatch-block is kept in action so long as the boat is kept in motion by a special transmission of movement J K, shown by fig. 2. It can be left free when it is not required by connecting with it an excellent system of clutch as shown on this page. This connection consists of the principal piece *A* which is in rough or cast iron, attached to the driving shaft and provided with a circular cavity. This cavity contains the wire *B*, the extremeties of which are connected with the rings *a*, *b*, on which the friction of the current operates.

The leading shaft receives a plate *F*, which is free to approach *cd* until it comes into contact by sliding on rollers.

When the current enters the wire *B* the armature of *F* connects itself with *cd* thus forming an electro-magnet and from it distributes its movement. The connection is therefore obtained without any exterior resistance; moreover by means of the angular form of the magnetic field the apparatus can also limit the maximum of power transmitted by allowing *A* to glide towards *F* when this power is exceeded.

The brake (see fig. 8) is provided with a guiding roller, by which the chain, even when in tension, is obliged when stationary to cling to an arc of a certain length on the magnetised snatch-block of the brake, so that as soon as the current is transmitted the chain and the articulated sheath attach themselves to it with certainty both at the same time.

The shaft of this block is not connected with any mechanism; it turns freely on its bearings, and the sheath regulated by a spring is arranged so as to come into contact with very little play and even with a weak current. Finally, the present installation necessitates in all, on the deck between the fore and aft vertical rollers $E\ E^1$, three magnetised snatch-blocks, a chain-well, three commutators mounted on the bridge for the working and the *rhéostats* placed below the deck. The source of the current is a dynamo with a special motor constructed by Messrs. SAUTTER HARLÉ & Co and is independent of the principal motor.

On trial the toueur-tug realised a speed in descending of 18 kilometres with 170 horse-power. The current was from 1 to 5 kilometres.

The new tow-boat is in regular service since the middle of the year 1893, and works in a satisfactory manner either as tow-boat a or a tug corresponding entirely to the plan in view of which it was constructed.

The Company has under its consideration projects for three new boats of the same type.

Various methods of traction.

Besides navigation convoys, in which boats of all kinds take part, the local traffic on large waterways is conducted by vessels of various sorts and extremely varied systems, which are dependent on the special conditions of the traffic and of the way. A certain number of examples of this kind will be found in the annexes.

Navigation on the Rhône.

It is known what difficulties are encountered by the navigation on the Rhône. The current is very rapid, the bed shifting and irregular, the depth of water very small and variable. Up to the present transports have been effected in various ways. Certain boats used principally for the transport of building materials are of wood, of large dimensions and small draught; descending, they drift with the tide, avoiding obstacles by the aid of long and powerful oars. On the ascent, which is always made empty, they are towed by numerous teams of horses and these are often obliged to enter the water up to the breast. A difficult and dangerous navigation, which can only be practised by bargemen of exceptional strength and dexterity.

The greater part of the transport is effected by steam-boats with paddle-wheels; these boats are very long, very narrow, very light, have a small draught of water and are supplied with powerful engines. Several of these boats also run a passenger service.

On the Rhône there are also some *grappins* and a few tugs to be seen. It is proposed to establish on this river a towage-service under peculiar conditions. The laying of a permanent chain would have given precarious results as it would be constantly displaced by the gravel. A proposal is now made to employ as the organ of traction a metal cable entirely surrounding an axle carried by the tow-boat. The tow-boat would immerse it when descending and take it up again when ascending.

Calculations are established for conducting the service in sections of about 20 kilometres with *traquage* at the extremities. It will be interesting to learn the results of this experiment, which will be on an original plan and work under very difficult conditions of navigation.

Passenger boats.

In spite of the competition of railways the passenger services by steamboats have been able to exist and to develope themselves on some sections of rivers which are favourably situated. This mode of transport is still much liked on account of its cheapness and the pleasure found in the mode of travelling. Large and fine passenger boats have been recently constructed very well arranged and supplied with powerful engines which allow them a high rate of speed. (See Annex IV.)

Many large towns on important rivers have a service of omnibus boats which carry passengers into the interior of the town and to places in the neighbourhood.

We should mention that among such services one of the most active and most prosperous in our country is that which serves the banks of the Seine where it traverses Paris. (1)

La Compagnie générale des Bateaux Parisiens employs for the transport of passengers in Paris and its neighbourhood, up and down the river, 105 boats in various types, each able to carry 225 to 400 passengers.

The total carrying power of these 105 boats is 28,275 passengers.

Among the various models of which this service is composed, the type represented on Plate II is one which complies best with the very peculiar requirements of the passenger service of Paris.

The following are the principal details regarding these boats:

Length	m. 29.50
Width on the deck	» 4.40
Maximum draught	» 2.15
Number of passengers	275
Tubular return-flame boiler registered at	k. 6
Compound engine, pilon type, developing 90 horse-power at 180 revolutions.	
A four-blade screw with a diameter of	m. 1.40
Number of turns of the screw	180
Rate of speed ascending	kilom. 17
» » » descending	» 18

Weights.

Engine	45,000 k.
Electricity	680 »
Boiler with water	10,000 »
Hull	22,000 »
Deck fittings	3,800 »
Fittings	7,000 »
275 Passengers	16,500 »
Various	396 »

The fuel employed is coke.

The rudder is governed by a wheel placed in the centre of the boat before the funnel. Transmission is effected by the medium of a cogged cylender and suitably placed tackle.

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(1) Information furnished by M. Caubet, administrateur délégué de la Compagnie.

CONCLUSIONS.

We will now briefly examine the subjects contained in the previous paragraphs and endeavour to draw from them some general conclusions and propositions to submit to the Congress at the Hague. We will consecutively consider Rivers and Canals.

Rivers.

From one river to another and even from one section to another section of a river, the methods of navigation vary greatly.

As regards boats travelling singly their conditions, their dimensions and their mode of propulsion depend essentially on local circumstances and on the nature of the traffic to be worked.

From the point of view we are taking it seems very difficult to draw from this whole any general conclusions without being vague and indefinite.

The same might almost be said on the subject of navigation in convoys. It is true that in the formation of convoys the models of the boats are sufficiently uniform; but among these boats are mixed other vessels of very various forms and dimensions. The traction apparatus, whatever it may be, must necessarily be suited to the way traversed, in other words must be an instrument essentially local.

Nevertheless, it may be useful to mention here the very active competition which has arisen on some waterways, and in particular on the Seine, between towing by means of tugs and toueurs. *Although we might be tempted to congratulate ourselves on this competition in consideration of the low price of transport at present in vogue, the situation is full of danger and may lead to disastrous consequences. It is the cause of extreme instability of prices and consequently the germ of a definite disorganisation of river navigation.*

Between these two systems of traction which both render such important services, the struggle is far from being equal. Among the different conditions the most powerful is the fact that the tug is independant, while the toueur *is bound down by a concession and a list of charges. These facts should not be lost sight of.*

From a purely technical point of view, important progress has been realised since the last Congress. We refer to the placing in working of the new magnetic-adherence tow-boat.

Canals.

Respecting towage on canals a step of great importance has likewise been accomplished since the last Congress. It is the introduction of electric towage on the dividing reach of the Burgundy Canal.

These two systems of applying electricity to navigation, adopted at the same time and both crowned with success, augur well for the future. Nevertheless, the problem of traction on canals cannot be considered as solved. At Pouilly navi-

gation is effected in convoys, and the question which now presents itself in canal matters is that of single boats. It should be remarked however that this question must not be considered as exclusively technical. In order to arrive at a good solution of it the problem should be very clearly put, for it is complicated with numerous considerations foreign to the art of engineering, and from which it cannot be disassociated, even if we confine ourselves strictly to the study of towage.

Thus, in the present state of things the expense of traction is the smallest part of the price of transport; the other expenses increase, not in proportion to distance, but in proportion to the time. In order to reduce them in any considerable manner it will not be sufficient to increase speed; it is above all, necessary to gain on time lost, which occurs in most various ways. This is above all a matter of administration and economical organisation.

From whatever point of view we regard it, it appears that mechanical traction substituted for towage by horses or by men is the true solution of the future, and that this alone will give its proper value to the magnificent system of navigable ways which covers our country. But before we arrive so far we have many obstacles to surmount: the abolition of ancient customs, the interference with vested interests economical and administrative conflicts, etc. It is an enormous transformation, almost a revolution.

In spite of all these difficulties the study of the problem is pursued with ardour. At the present time it appears that the preference is divided between two solutions. One, funicular towage, has been submitted to a practical and prolonged trial, which in spite of some mistakes of detail has allowed us to appreciate the great value of the system; the other, magneto-electric towage, is only as yet a project, but considering the recent progress made in electricity and the information already possessed upon the question, it appears to have considerable chances of success.

Propositions to be submitted to the Congress.

The Congress of Paris, after an exhaustive discussion of methods of traction, has proposed by way of conclusion a certain number of questions to be solved. (See Annexes).

Since the closing of the Congress these questions have been the object of study and have been will thrashed out.

Nevertheless it cannot be said that final solutions have been arrived at.

We consider, therefore, that these same questions must still be maintained in the programme of the studies of navigation congresses.

In addition, taking into account the recently acquired experience, we consider it necessary to strongly recommend that researches should be made with a view to the establishment of electric traction on canals.

Paris, April the 26th 1894. J. HIRSCH.

PART II.

Influence of the build of boats and the condition of their surface on the resistance to traction.

BY

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Ingénieur en Chef des Ponts et Chaussées.

The object of the present report is togive a brief account of the experiments which we have followed up on this subject during the four years 1890, 1891, 1892 and 1893. We will not speak here of the methods, nor of the apparatus employed (1).

We will confine ourselves to pointing out the principal results arrived at.

It is, however, indispensable that it should be remembered that our experiments have been made exclusively on boats capable of navigating alternately the rivers and the canals of France, that is, able to pass through locks of 38.50 m. in length, 5.20 m. in width, and at least 2 m. in depth. It should be added that during the first three years the experiments took place on the Seine in a part sufficiently wide and deep to be assimilated to any undefined waterway. In 1893, on the contrary, they were made on the Burgundy Canal, hence the division of the report in two sections.

FIRST SECTION.

EXPERIMENTS MADE ON THE SEINE.

Influence of Surface.

We have first examined how on the same boat the resistance to traction varies with the draught. With this object experiments were made on the *Alma*, a boat of the type called *flûte* (Pl. IV) when drawing successively 1 m.,

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(1) For these details we can only refer our readers to the works entitled: „*Recherches expérimentales sur le matériel de la Batellerie*". Two of these have already appeared, and are on sale in Paris at the following addresses: M^{me} V^{ve} DUNOD, quai des Grands Augustins 49; Messrs. CHAIX & Co, Rue Bergère 20; M^{r} BAUDRY, Rue des Saints-Pères 15. A third work is in course of preparation.

1.30 m. and 1.60 m. The table below shows the principal dimensions at these different draughts.

Dimensions of the hull of the *Alma* below water.	At a Draught of		
	1.00 m.	1.30 m.	1.60 m.
L. Length	37.54 m.	37.74 m.	37.99 m.
l. Width amidship	5.02	5.02	5.02
t. . Draught	1.00	1.30	1.60
δ. Coefficient of displacement	0.957	0.954	0.950
D. Displacement.	180 cm.	235 cm.	290 cm.

The second table shows how the section below water amidships, the total of the wet surface, and the resistance to speeds of 0.50 m., 1.00 m., 1.50 m., 2.00 m. and 2.50 m. vary with the different draughts, both in absolute, as well as in relative value. (The figures which express the relative values are underlined.)

Date and results relative to the *Alma*.		At a draught of		
		1.00 m.	1.30 m.	1.60 m.
Section below water amidships. Value	absolute $\omega = lt$	5.02 sq.m.	6.53 sq.m.	8.03 sq.m.
	relative . . .	1.00 „	1.30 „	1.60 „
Perimeter below water amidships : $(X = l + 2t)$.		7.02 m.	7.62 m.	8.22 m.
Length L below water		37.54 m.	37.74 m.	37.99 m.
Total wet surface .	by measurement	259 sq.m.	283 sq.m.	307 sq.m.
	calculated $(S = L X)$. . .	264 „	288 „	312 „
	relative value	1.00 „	1.09 „	1.18 „
Total resistance at a speed of 0.50 m.	absolute .	39 k.	44 k.	54 k.
	relative .	1.00 „	1.13 „	1.38 „
„ „ „ „ „ „ 1.00 m.	absolute .	129 k.	143 k.	162 k.
	relative .	1.00 „	1.11 „	1.26 „
„ „ „ „ „ „ 1.50 m.	absolute .	280 k.	315 k.	355 k.
	relative .	1.00 „	1.13 „	1.27 „
„ „ „ „ „ „ 2.00 m.	absolute .	502 k.	579 k.	664 k.
	relative .	1.00 „	1.15 „	1.32 „
„ „ „ „ „ „ 2.50 m.	absolute .	805 k.	953 k.	1119 k.
	relative .	1.00 „	1.18 „	1.39 „

It results from the above figures that:

1st *The section below water amidships* increases in proportion to the draught.

2nd *The total wet surface* below water increases at a lesser rate than the draught.

3rd *The total resistance* for the same speed increases less rapidly than the *section below water amidships* and more rapidly than the *total wet surface.*

The fact may be explained if we consider the *total resistance* as composed of at least two elements, one depending on the section below water amidships, the other on the total wet surface. We will call these elements respectively: *Resistance due to build* and *Resistance of surface.*

What part of the *Total resistance* does the *Resistance of surface* form?

In order to elucidate this point we made with the *Alma* a number of experiments with the object of discovering what alteration in the *Total resistance* would result from various alterations brought about in the nature of the surface of the boat, all other things remaining the same. These different experiments gave similar results and we confine ourselves to mentioning the most characteristic.

The experiment consisted in noting the resistance of the *Alma* at a draught of 1.60 m. firstly, with the hull in its usual state; secondly, when it was completely covered with oil-cloth so as to diminish friction as much as possible. The results are given in the following table:

Speed.	Total resistance of the *Alma*.		Decrease.	
	Hull in natural state.	Covered with oil-cloth.	Absolute.	Relative.
	Kilogrammes.	Kilogrammes.	Kilogrammes.	
0.50 m.	54	28	26	0.48
1.00 m.	162	105	57	0.35
1.50 m.	355	250	105	0.30
2.00 m.	664	480	184	0.28
2.50 m.	1,119	812	307	0.27

The considerable importance of the *Resistance of surface* is shown here at a glance. At a draught of 1.60 m. and a speed of 1.50 m. per second, for example, the total resistance of the *Alma* was reduced 30 °/₀ by the sole means of replacing the rather rough surface of the hull by a perfectly smooth one (oil-cloth). As, on the other hand, the friction on the oil-cloth, although extremely feeble, is not absolutely non-existent, it must be concluded that, *in the given conditions of draught and of speed the resistance due to the friction of the water on the hull in its natural state was about one third of the total resistance.*

Influence of length.

We have experimented with three boats of the *flûte* type, viz. the *Alma*, the *René* and the *Adrien*, having the same width of 5.02 m. amidships, and presenting fore and aft shapes as identical as possible, and differing only in length.

With a draught of 1.60 m. the length of hull below water was as follows:

Alma	37.99 m.
René	30.03 m.
Adrien	20.55 m.

The three boats presented exactly the same resistance to traction, as shown in the figures of the table below.

Names of the boats.	Resistance at speeds of:				
	0.50 m.	1.00 m.	1.50 m.	2.00 m.	2.50 m.
	Kilos.	Kilos.	Kilos.	Kilos.	Kilos.
Alma	54	162	355	664	1119
René	51	160	355	665	1120
Adrien	51	160	355	665	1120

This result (1) seems at first sight paradoxical and in complete contradiction with the previously demonstrated existence of a *Resitance of surface*. This, however, is explained in a plausible manner if, in conformity with the ideas of du Buat, we admit that the *Resistance due to build* is equal to the sum of the *Pressure* acting on the fore-part and the *Nonpressure* on the after-part of the boat, the first independently of its length, and the second varying in inverse ratio to this length, or rather as the ratio between the length and the width.

The shape of the *Alma*, the *René* and the *Adrien* being considered as identical, the *Pressure* is the same for all three; but for boats of less length, the *Non-pressure* is more considerable, and this is consequently the same with the *Resistance due to build*. It may thus be admitted that with these boats the increase in the *Resistance due to build* resulting from the shorter length is exactly compensated by the diminution in the *Resistance of surface* resulting from the same cause.

We will admit therefore: 1st *that, all other things being equal, the Resistance due to build varies in inverse ratio to the ratio* $\frac{L}{l}$ *between the length of the boat and its width amidships*; 2nd *that within the limits and the conditions in which our experiments have been made the total Resistance of a boat is independnt of its length, provided that all other things rəmain the same.*

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(1) It has been confirmed under equally remarkable conditions on the *Alma*, and the *René* with a draught of 1.30 m.

Influence of the build.

The influence of form is shown in the two tables given below in which we have collected all the data relating to boats of different types, together with their resistance to traction at speeds of 0.50 m., 1.00 m., 1.50 m. 2.00 m. and 2.50 m.

The first table gives the results at the common draught of 1.60 m. on a *péniche*, the *Dalila*, on a *flûte*, the *Alma* and on a *toue*, the *Désirée* (Pl. IV), all three being as exactly as practically possible of the same length, width and condition of surface.

Dimensions of boats and resistance to traction.	Names of the boats.		
	Péniche *Dalila.*	Flûte *Alma.*	Toue *Désirée.*
Dimensions below water.			
L. Length	38.16 m.	37.99 m.	37.76 m.
l. Width amidships	5.00 m.	5.02 m.	5.03 m.
Ratio $\frac{L}{l}$	7.64	7.57	7.51
t. Draught	1.60 m.	1.60 m.	1.60 m.
δ. Coefficient of displacement	0.990	0.950	0.966
D. Displacement	302 cub.m.	290 cub.m.	294 cub.m.
Total resistance at a speed of:			
0.50 m. per second	102 k.	54 k.	44 k.
1.00 m. " "	301 k.	162 k.	126 k.
1.50 m. " "	682 k.	355 k.	266 k.
2.00 m. " "	1287 k.	664 k.	484 k.
2 50 m. " "	—	1.119 k.	806 k.
Resistance per cubic metre (or ton) of displacement at a speed of:			
0.50 m. per second	0.337 k.	0.186 k.	0.151 k.
1.00 m. " "	0.996 k.	0.558 k.	0.430 k.
1.50 m. " "	2.251 k.	1.224 k.	0.907 k.
2.00 m. " "	4.261 k.	2.289 k.	1.646 k.
2.50 m. " "	—	3.858 k.	2.750 k.
Resistance at a speed of 1 metre per square metre of section below water amidships	37.6 k.	20.2 k.	15.7 k.

The figures of the above table afford crushing evidence of the inferiority of the *péniche* type, which is however not surprising; but they also show the superiority of the *toue* type to the *flûte* type, which could not have been foreseen *a priori*. The fact is the more remarkable, as the *flûte* is not only pointed at the bows, but is also more or less cut away in the stern; whereas the *toue* is only sharp in the bows, the after-part being absolutely square. It appears therefore that the raising of the cut-water has the most effect.

The figures of the second table cannot leave any doubt as to the influence of raising the ends. It comprises the comparative results of experiments made on the *flûte Alma* and on two types of boats considerably raised both fore and aft. Viz. the *margotat Suffren*, and the Prussian boat *Remesch* (Pl. IV). These last experiments could only be made with a draught of 1.30 m., this being the maximum realisable draught with boats of the two last named types. Although these boats had obviously the same width and same condition of surface as the *Alma*, they differed from it considerably in length. Their length did not, however, exceed the limits within which we have found that for this type of boat the total resistance is independent of the length.

It seems thus plausible to admit that the total resistance of the *margotat* would not increase if the length below water was increased from 20.30 m. to 37.74, the length below water of the *Alma*; and the same would be the case with the Prussian boat if its length was increased from 34.10 m. to 37.74 m.

For each of these boats the table contains two columns, one showing the figures as they were really taken, and the other with the figures calculated on the above hypothesis.

Dimensions of the boats and resistance to traction.	Names of tbe boats.				
	Flôte	Margotat.		Prussian boat.	
	Alma.	*Suffren.*	of same length below water as the *Alma.*	*Remesch.*	of same length below water as the *Alma*
Dimensions below water.					
L. Length	37.74 m.	20.30 m.	**37.74** m.	34.10 m.	**37.74** m.
l. Width amidships	5.02 m.	5.00 m.	**5.00** m	4.91 m.	**4.91** m.
Ratio $\frac{L}{l}$	7.52	4.06	**7.55**	6 94	**7.69**
t. Draught	1.30 m.	1.30 m.	**1.30** m.	1.30 m.	**1.30** m.
δ. Coefficient of displacement	0.954	0.818	**0.914**	0.935	**0.937**
D. Displacement	235 cm.	108 cm.	**224** cm.	203 cm.	**226** cm.

Dimensions of the boats and resistance to traction.	Names of the boats.				
	Flûte	Margotat.		Prussian boat.	
	Alma.	*Suffren.*	of same lenght below water as the *Alma*	*Remesch.*	of same lenght below water as the *Alma*
Total resistance at a speed of:					
0.50 m. per second	44 k.	21 k. (1)	**21 k.**	22 k.	**22 k.**
1.00 m. „ „	143 k.	67 k. (1)	**67 k.**	80 k.	**80 k.**
1.50 m. „ „	315 k.	140 k.	**140 k.**	185 k.	**185 k.**
2.00 m. „ „	579 k.	243 k. (1)	**243 k.**	349 k.	**349 k.**
2.50 m. „ „	953 k.	377 k.	**377 k.**	582 k.	**582 k.**
Resistance per cubic metre (or ton) of displacement at a speed of:					
0.50 m. per second	0.187 k.	0.194 k.	**0.094 k.**	0.108 k.	**0.097 k.**
1.00 m. „ „	0.609 k.	0.620 k.	**0.299 k.**	0.394 k.	**0.354 k.**
1.50 m. „ „	1.340 k.	1.296 k.	**0.625 k.**	0.911 k.	**0.819 k.**
2.00 m. „ „	2.464 k.	2.250 k.	**1.085 k.**	1.719 k.	**1.544 k.**
2.50 m. „ „	4.055 k.	3.491 k.	**1.683 k.**	2.867 k.	**2.575 k.**
Resistance at a speed of 1 metre per square metre of section below water amidships	21.9 k.	10.3 k.	**10.3 k.**	12.5 k.	**12.5 k.**

According to the first table (draught of 1.60 m.), if we take as unit the total resistance of the *péniche* at a speed of 1.50 m., we see that at the same speed the total resistance of the *flûte* is not more than 0.52, and that of the *toue* falls to 0.39.

At the same speed the resistances per cubic metre (or ton) of displacement are respectively 1.00, 0.54 and 0.40.

According to the second table (draught of 1.30 m.), if we take as unit the total resistance of the *flûte* at a speed of 1.50 m., we see that at the same speed the total resistance of the Prussian boat is not more than 0.59, and that of the *margotat* falls to 0.44. The resistances per cubic metre (or ton) of displacement are respectively: 1.00, 0.61 and 0.47.

We are therefore justified in thinking that by raising the bow and the stern a type might be arrived at of which the resistance to traction *in rivers* would not be more than a *quarter* of that of the *péniches*.

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(1) In consequence of an error on page 56 and in the Plate XVII of „*Recherches experimentales sur le matériel de la batellerie*," these resistances were given as 28, 72 and 239 kilogrammes respectively.

It is true that it is the *margotat* which has given the most satisfactory results as regards resistance to traction, but it is also this type which has the least displacement, and again the disadvantage which it presents from this point of view becomes rapidly greater in proportion as the draught increases, as we will show later on.

Consequently, and also with the object of obtaining superior nautical qualities, we are of opinion that it would be well to give to the extremities a form more nearly approaching that of the extremities of the Prussian boat, in fact something the shape of a spoon.

In this way we have studied in a purely geometrical manner two theoretical types, differing however only in their rake, and which are shown on Plate V.

The first type has a length of 38.58 m. over-all measurement, and a keel of 33.58 m.

On this latter the section is uniform and rectangular, 5.00 m. wide and 2.20 m. in height. The two extremities are identical. They are shaped longitudinally as follows: 1st a quarter ellipse of which half the vertical axis is 2.20 m. and half the horizontal axis 2.50 m. in length; 2nd a vertical part of 0.40 m. corresponding to the rounding of the boat. The length below water at a draught of 1.80 m. is exactly 38.50 m. The waterlines determined by horizontal planes arranged in degrees of 0.20 to 0.20 m. are in the aft and fore curves all elliptical and consequently the contour of the extremities on the horizontal is circular.

The second type differs from the first only in that half axis of the ellipses formed by the extremities are 4.50 m. in length instead of 2.50 m. The length below water at a draught of 1.80 m. remains 38.50 m. The length over-all measurement is 38.64 m., and that of the keel is reduced to 29.64 m.

The exclusive adoption of these geometrical lines allows us to calculate very rapidly, for a given draught, the real displacement and the coefficient of displacement in the two types.

With a draught of 1.80 m. (1) the legal draught of France:

we have for the 1st type: $D = 328 \text{ T} \quad \delta = \frac{328}{38.50 \times 5.00 \times 1.80} = 0.947.$

and for the 2nd type: $D = 313 \text{ T} \quad \delta = \frac{313}{38.50 \times 5.00 \times 1.80} = 0.904.$

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(1) With a draught of 1.30 m. the real displacement and the coefficient of displacement are respectively: for the 1st type, 235 T. and 0.948, and for the 2nd type 222 T. and 0.903.
With a draught of 1.60 m. the same data become respectively: for the 1st type 291 T. and 0.946 and for the 2nd type 277 T. and 0.903.

A *margotat* measuring as the second type 38.64 m. in length over-all measurement, 5.00 in width, and 2.20 m. in height amidships, with 0.40 m. of bulge would not have more than 293 tons of real displacement with a draught of 1.80 m. The coefficient of displacement would still reach 0.893, but the length on the water-line would be reduced to 36.44 m.

SECOND SECTION.

EXPERIMENTS MADE ON THE BURGUNDY CANAL.

The experiments were made on a straight stretch, 1600 metres in length, the transverse section of which is larger than the legal section of French canals. It is known that the latter is fixed at 10.00 m. at the bottom and 16.00 m. at the waterline with a depth of 2.00 m., which gives a wet surface of 26 square metres.

On the portion of the Burgundy canal we are refering to, the wet surface of the transverse section averages 29.53 sq. m.; it never exceeds 29.78 sq. m. nor becomes less than 29.13 sq. m. Its regularity, therefore, leaves nothing to be desired.

This average wet surface of 29.53 sq. m. corresponds to average dimensions as follows:

Width at bottom	**8.30 m.**
» » water-line	**18.70 »**
Wet surface	**2.19 »**

The experiments were made on nine boats (See Pl. IV).

The *péniche Mascaret*, which is similar to the *péniche Dalila*; four *flûtes*, viz. the *Avant-Garde* similar to the *flûte Alma*, the *Jeanne* and the *Petite-Jeanne*, which only differ from the *Alma* in their length (1), the *Paulin*, which possesses the peculiarity of having a square stern like the *toues*; further, two *toues*, the *Gambetta* which is identical with the *Desirée* and the *Celestin* which only differs from the *Desirée* in length; the *margotat Suffren*; and the Prussian boat *Remesch*.

All data relating to these boats, with the different draugh's at which the experiments were made will be found in the following tables, together with their resistance to traction at speeds varying from 0.25 m. to 0.25 m. up to 1.25 m. inclusively.

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(1) It is necessary to remark that the *Petite Jeanne* is a little more slender in the stern than the two others.

Dimensions of the boats below water.		Descriptions of the boats on which experiments were made.								
		Péniche.	Flûtes.				Toue.		Margotat.	Prussian boat.
		Mascaret.	Paulin.	Avant-Garde.	Jeanne.	Petite Jeanne.	Gambetta	Célestin.	Suffren.	Romesch.
	At a draught of 1.00 *m.*									
L.	Length	38.17 m.	38.14 m.	37.52 m.	29.80 m.	24.26 m.	37.43 m.	29.60 m.	19.20 m.	33.70 m.
l.	Width amidships	5.03 m.	5.02 m.	5.02 m.	5.01 m.	5.02 m.	5.02 m.	5.02 m.	5.00 m.	4.91 m.
	Ratio $\frac{L}{l}$	7.59	7.60	7.47	5.95	4.83	7.46	5.90	3.84	6.86
δ.	Coefficient of displacement	0.992	0.968	0.957	0.951	0.931	0.980	0.977	0.888	0.954
D.	Displacement	190c.m.	185c.m.	180c.m.	142c.m.	113c.m.	184c.m.	145c.m.	79c.m.	161c.m.
	At a draught of 1.30 *m.*									
L.	Length	38.25 m.	38.34 m.	37.70 m.	30.00 m.	24.50 m.	37.68 m.	29.85 m.	20.30 m.	34.10 m
l.	Width amidships	5.03 m.	5.02 m.	5.02 m.	5.01 m.	5.02 m.	5.02 m.	5.02 m.	5.00 m.	4.91 m.
	Ratio $\frac{L}{l}$	7.60	7.63	7.51	5.99	4.88	7.51	5.95 m.	4.06	6.94
δ.	Coefficient of displacement	0.990	0.966	0.954	0.946	0.927	0.978	0.973	0.818	0.935
D.	Displacement	247c.m.	242c.m.	235c.m.	185c.m.	148c.m.	241c.m.	190c.m.	108c.m.	203c.m
	At a draught of 1.60 *m.*									
L.	Length	38.25 m.	38.39 m	37.93 m.	30.17 m.	—	37.92 m.	30.09 m.	—	—
l.	Width amidships	5.03 m.	5.02 m.	5.02 m.	5.01 m.	—	5.02 m.	5.02 m.	—	—
	Ratio $\frac{L}{l}$	7.60	7.64	7.56	6.02	—	7.55	5.99	—	—
δ.	Coefficient of displacement	0.988	0.963	0.950	0.944	—	0.972	0.968	—	—
D.	Displacement	304c.m.	297c.m.	290c.m.	288c.m.	—	297c.m.	234c.m	—	—
	At a draught of 1.80 *m.*									
L.	Length	—	38.50 m.	—	—	—	—	—	—	—
l.	Width amidships	—	5.02 m.	—	—	—	—	—	—	—
	Ratio $\frac{L}{l}$	—	7.67	—	—	—	—	—	—	—
δ.	Coefficient of displacement	—	0.960	—	—	—	—	—	—	—
D.	Displacement	—	334c.m.	—	—	—	—	—	—	—

Total resistance to traction.		Names of the boats on which experiments were made.								
		Péniche.	Flûtes.				Toues.		Margotat.	Prussian boat.
		Mascaret.	Paulin.	Avant-Garde.	Jeanne.	Petite Jeanne.	Gambetta	Célestin.	Suffren.	Remesch.
At a draught of 1.00 m.										
At a speed per second of:	0.25 m.	22 k.	16 k.	16 k.	16 k.	15 k.	16 k.	16 k.	13 k.	13 k.
	0.50 m.	73 k.	50 k.	48 k.	47 k.	44 k.	46 k.	46 k.	34 k.	38 k.
	0.75 m.	163 k.	112 k.	106 k.	103 k.	96 k.	100 k.	100 k	69 k.	81 k.
	1.00 m.	296 k.	203 k.	191 k.	185 k.	172 k.	178 k.	178 k.	118 k.	145 k.
	1.25 m.	510 k.	350 k.	327 k.	314 k.	292 k.	300 k.	300 k.	196 k.	249 k.
At a draught of 1.30 m.										
At a speed per second of:	0.25 m.	33 k.	23 k.	22 k.	22 k.	21 k.	22 k.	22 k.	17 k.	17 k.
	0.50 m.	114 k	76 k.	70 k.	70 k.	66 k.	68 k.	68 k.	53 k.	54 k.
	0.75 m.	256 k.	173 k.	156 k.	155 k.	146 k.	150 k.	150 k	112 k.	119 k.
	1.00 m.	469 k.	320 k.	284 k.	282 k.	263 k.	272 k.	272 k.	197 k.	215 k.
	1.25 m.	807 k.	561 k.	491 k.	487 k.	451 k.	469 k.	469 k.	335 k.	370 k.
At a draught of 1.60 m.										
At a speed per second of:	0.25 m.	43 k.	33 k.	32 k.	32 k.	—	32 k.	32 k.	—	—
	0.50 m.	172 k.	117 k.	112 k.	111 k.	—	109 k.	108 k.	—	—
	0.75 m.	415 k.	271 k.	258 k.	255 k.	—	249 k.	247 k.	—	—
	1.00 m.	860 k.	506 k.	481 k.	475 k.	—	463 k.	456 k.	—	—
	1.25 m.	1687 k.	892 k.	845 k.	834 k.	—	811 k.	792 k.	—	—
At a draught of 1.80 m.										
At a speed per second of:	0.25 m.	—	43 k.	—	—	—	—	—	—	—
	0.50 m.	—	172 k.	—	—	—	—	—	—	—
	0.75 m.	—	410 k.	—	—	—	—	—	—	—
	1.00 m.	—	800 k.	—	—	—	—	—	—	—
	1.25 m.	—	1487 k.	—	—	—	—	—	—	—

Influence of length.

If we compare the results obtained at the different draughts on the *flûtes Avant-Garde*, *Jeanne* and *Petite Jeanne*, on the one hand, with the *toues Gambetta* and *Célestin*, we arrive at the conclusion that on the canal as well as on the Seine the *total Resistance* on one type is independent of its length, at least within the limits and under the conditions in which our experiments were made.

As regards the two *toues* the results may be considered absolutely identical;

the greatest difference verified, that is, resistance at a speed of 1.25 m. with a draught of 1.60 m., does not exceed 19 kilogrammes in absolute value and 2.3 °/₀ in relative value.

For the two *flûtes Avant-Garde* and *Jeanne* the results are obviously the same. The greatest difference verified at a speed of 1.25 m. with a draught of 1.00 m. was 13 kil. in absolute value and 4 °/₀ in relative value.

Between the two flûtes *Avant-Garde* and *Petite Jeanne* the difference oı resistance was more considerable. At every draught and at every speed a diminution in favour of the *Petite Jeanne* was observed; and this diminution was remarkable, in one case exceeding 10 °/₀ of the relative value. There is certainly nothing surprising in the fact that the limits in which the total resistance of one type is independent of the length are not the same on canals and rivers; but this diminution of resistance on the *Petite Jeanne* may well be explained by the point mentioned above, viz. that this *flûte* is a little sharper in the stern than the two others.

The influence of the form of the stern appears really considerable; and this is shown by a comparison of the results obtained with the two *flûtes Paulin* and *Avant-Garde*. As we have already said these two boats differ only in so far that the after part of the *Paulin* is square while the stern of the *Avant-Garde* is sharp, as was usual in the normal type of *flûte*. This point is sufficient to secure a certain advantage to the latter.

Influence of the build.

In order to make a comparison which would apply at the same time to all of the characteristic types, we have been obliged to take a draught of 1.30 m., this being the maximum draught, at which experiments could be made on the *margotat* and the Prussian boat. In the following table, which gives all the elements of this comparison, we have however only quoted one *flûte*, the *Avant-Garde*, which is of the normal type, and only one *toue* the *Gambetta*.

Finally, with the object of having figures that may be compared especially as regards displacement and resistance per ton of displacement, we have in the table reduced all the boats to one length. After what we have said above concerning the influence of length we have every reason to believe ourselves justified in so doing.

Dimensions of the boats and their resistance to traction.	Description of the boats.				
	Péniche.	Flûte	Toue.	Margotat	Prussian boat.
Dimensions below woter.					
L. Length	38.25 m.	38.25 m.	38.25 m.	38.25 m.	38.25 m.
l. Width amidships	5.03 m.	5.02 m.	5.02 m.	5.00 m.	4.91 m.
Ration $\frac{L}{l}$	7.60	7.62	7.62	7.65	7.79
t. Draught	1.30 m.	1.30	1.30 m.	1.30 m.	1.30
δ. Coefficient of displacement	0.990	0.954	0.979	0.903	0.940
D. Displacement	247 c.m.	238 c.m.	244 c.m.	225 c.m.	230 c.m.
Total resistance at a speed of:					
0.25 m. per second	33 k.	22 k.	22 k.	17 k.	17 k.
0.50 " " "	114 k.	70 k.	68 k.	53 k.	54 k.
0.75 " " "	256 k.	156 k.	150 k.	112 k.	119 k.
1.00 " " "	469 k.	284 k.	272 k.	197 k.	215 k.
1.25 " " "	807 k.	491 k.	469 k.	335 k.	370 k.
Resistance per cubic metre (or ton) of displacement at a speed of:					
0.25 m. per second	0.134 k.	0.092 k.	0.090 k.	0.076 k.	0.074 k.
0.50 " " "	0.462 k.	0.294 k.	0.279 k.	0.236 k.	0.235 k.
0.75 " " "	1.036 k.	0.655 k.	0.615 k.	0.498 k.	0.517 k.
1.00 " " "	1.899 k.	1.193 k.	1.115 k.	0.876 k.	0.935 k.
1.25 " " "	3.267 k.	2.063 k.	1.922 k.	1.489 k.	1.609 k.
Resistance at a speed of 1 m. per sq.m. of section below water amidships	71.7 k	43.5 k.	41.7 k.	30.3 k.	33.7 k.

If, in conformity with what we have said above about the peculiar difficulties connected with the *margotat*, we put this type on one side, in spite of its apparent advantages, we see that the Prussian boat maintains on canals the superiority with which it had been credited on rivers.

We are therefore justified in thinking that boats the extremities of which are fashioned in the spoon-form (Pl. V) are to be recommended for the navigation of canals as well as for the navigation of rivers.

On the latter, where the towing is usually effected by means of steam-tugs, the power developed by the motor can be limited to the force strictly necessarv for the traction of the boats tugged. On canals, on the contrary, single boats are generally drawn by horses, and these constitute a constant motive power. To completely utilise this power it would be necessary to vary the speed. Most frequently the horses are harnessed in pairs under the guidance of a driver. These horses go at a walking pace, at a speed which is to a certain degree necessarily variable. According to certain detailed information we estimate the continuous labour of a pair of horses under these conditions at 117 kilogrammetres per second. It is easy to determine on the curve of total resistance of each boat the speed at which the product of speed with resistance is equal to 117 kilogrammetres.

For the boats in the table above (draught of 1.30 m.) this speed is respectively:

Péniche	**0.64 m.**
Flûte	**0.75 »**
Toue	**0.76 »**
Prussian boat	**0.83 »**

The adoption of forms of less resistance would as regards the *péniche* thus allow of the realisation of an increase of speed of about 30 $^{0}/_{0}$. Likewise it is certain that the adoption of such forms would also have the result of shortening the time occupied in lock-working.

Comparison between resistance on canals and resistance on rivers.

On passing from a river of which the section may be considered as unlimited to a canal of which the section is on the contrary very limited, the resistance to traction naturally increases in very considerable proportions. We may judge of this by the following table where will be found the verified results of trials at different draughts and at speeds of 0.50 m. and of 1 m. per second which seem to represent the extreme limits of speed practised and practicable on our canals. We will call:

Ω the wet section of the canal;

ω the section of the boat below water amidships;

R the total resistance to traction in canals;

r the total resistance to traction in rivers;

$\frac{R}{r}$ is the ratio between these two resistances corresponding to the ratio $\frac{\Omega}{\omega}$ between the sections.

Draught and description of boats.	Ω	ω	$\frac{\Omega}{\omega}$	At a speed of 0.50 m.			At a speed of 1.00 m.		
				R.	*r.*	$\frac{R.}{r.}$	R.	*r.*	$\frac{R.}{r.}$
At a draught of 1.60 m.									
Péniche	29.53 sq.m.	8.05sq.m.	3.67	172 k.	102 k.	1.69	860 k	301 k.	2.86
Flûte	29.53 sq.m.	8.03sq.m.	3.68	112 k.	54 k.	2.07	481 k.	162 k	2.97
Toue	29.53 sq.m.	8.03sq.m.	3.68	109 k.	44 k.	2.48	463 k.	126 k.	3.67
At a draught of 1.30 m.									
Flûte	29.53 sq.m.	6.53sq.m.	4.52	70 k.	44 k.	1.59	284 k.	143 k.	1.99
Prussian boat	29.53 sq.m.	6.38sq.m.	4.62	54 k.	22 k.	2.45	215 k.	80 k.	2.69
Margotat	29.53 sq.m.	6.50sq.m.	4.54	53 k.	21 k.	2.52	197 k.	67 k.	2.94
At a draught of 1.00 m.									
Flûte	29.53 sq.m.	5.02sq.m.	5.88	48 k.	39 k.	1.23	191 k.	129 k.	1.48

We see, firstly, that for one value of the ratio $\frac{\Omega}{\omega}$ the increase of resistance in passing from the river into the canal was as much greater as the resistance of the boat in the river was less. *The build is less important on canals than on rivers.*

It should be observed too with what rapidity the ratio of resistance $\frac{R}{r}$ decreases when the ratio of the sections $\frac{\Omega}{\omega}$ increases. Thus, for the *flute* we gather the following results:

Draught.	Ratio of sections $\frac{\Omega}{\omega}$	Ratio of resistances $\frac{R}{r}$	
		speed of 0.50 m.	speed of 1.00 m.
1.60 m.	3.68	2.07	2.97
1.30 m.	4.52	1.59	1.99
1.00 m.	5.88	1.23	1.48

This question of ratio of sections is of capital importance, but we are not yet in a position to discuss it completely. We see from the above example how the increase of resistance varies in one and the same canal and one and the same boat, when the draught of the latter and consequently its section below water amidships vary. It is especially necessary to learn how the resistance of one and the same boat varies when passing from one canal into another of a different section. We trust that in the course of the present campaign we shall be able to make experiments necessary to enlighten us on this point.

M. B. DE MAS.

Paris, April the 26th 1894.

ANNEX I.

Resolutions voted by the Paris Congress concerning Traction on Navigable Ways.

„1st It is very desirable that experimental researches should be made con- „cerning the distribution of traction power in the various reaches of canalised „rivers, following the method adopted for the experiments which are at „present being pursued on the Basse-Seine by M. CAMERÉ and CLERC, „and of which an account has been given by M. CAMERÉ in his report.

„2nd Considering that funicular towage would constitute a practical solution „of the question of traction on canals of large traffic, if the twisting of the cable, „which still sometimes occurs in spite of the precaution taken to avoid it, could „be prevented, the section expresses its wish that the experiments of St. Maur „on the one hand, and those on the Canal from the Oder to the Spree on „the other hand be continued with the special object of studying the causes „of the twisting and above all to find a remedy against the hindrance which it may still exercise in the towage of boats.

„3rd The section wishes that, besides experiments in funicular towage, „experiments be also made in the employment of the system of electrical „towage invented and explained by M. DE BOVET.

„4th It is desirable that every boat be provided as soon as possible with an „official document showing its resistance to traction at different relative speeds.

„5th The section appreciating the importance of the experiments under- „taken by M. DE MAS wishes that these experiments be followed up in all „their details and especially with reference to the influence of the condition „of surfaces on resistance to traction.

„6th The section wishes that the question of better economical organisation „of traction on navigable ways be submitted to the next Congress."

ANNEX II.

Towage on rivers.

Compagnie de touage et transports de la Seine de Conflans à la mer (*a*).

This Company provides the service between Conflans (mouth of the Oise) and Rouen (171 km.).

(*a*) Information furnished by M. CARIMANTRAND, administrateur délégué de la Cie.

It owns eight tow-boats, constructed on the same type and having the following dimensions.

Length	40.50 m.
Width	6.30 »
Depth amidship	2.30 »
Displacement in service about	200 tons.
Engine	120 horse-power.

These boats can tow 4000 to 5000 tons nett weight.

By the aid of a system of gearage two rates of speed may be made. The engine working at 60 or 70 revolutions gives 4 km. an hour at low speed and 6 to 7 km. at full speed.

The boats are furnished with screws which allow them to work freely as tug-boats.

Each tow-boat travels the entire distance without *traquage*. The exchange of the chain with descending boats is effected by means of hooks which are placed at distances of about 100 m. on the chain. The operation takes 25 to 30 minutes.

Compagnie anonyme de touage de la Basse Seine et de l'Oise (*a*).

This Company works the river Oise and the Seine between Conflans (mouth of the Oise) and the lock de la Monnaie in Paris.

It possesses 7 tow-boats of which the dimensions of 5 of them are:

Length	32.00 m.
Width	5.80 »
Draught of water	1.20 »

and of the 2 others:

Length	42.00 m.
Width	5.80 »
Draught	0.90 »
Indicated horse-power	110 »

At high-water (when the dams are lowered) these boats can draw 5 *péniches* (1400 tons nett weight) at a speed of $3^{1}/_{2}$ km.

With favorable high-water in summer the load of the tow-boats might be trebled, but generally complete trains do not consist of more than 12 *péniches* (3400 tons) and travel at $4^{1}/_{2}$ km.

The Company established in the course of the year 1892 magnetic towage as previously described.

Compagnie de touage de la Haute-Seine (*b*).

This Company works the section of the Seine comprised between the lock de la Monnaie in Paris and Montereau, on a length of 175 km.

(*a*) Information furnished by M. DE BOVET, Directeur de la C^{ie}.

(*b*) Information furnished by M. LASMOLLES, Directeur de la C^{ie}.

The tow-boats have the following dimensions:

Length	30.00 m.
Width	8.00 »
Draught	0.60 »
Horse power, about	35.
Maximum burden, about . . .	1500 tons.
Speed	4 km. per hour.

For several years past the service has been worked both by day and by night.

The Company also possesses three screw tug-boats of 150, 178 and 200 horse-power respectively.

Compagnie générale de navigation Hâvre-Paris-Lyon-Marseille. (*a*)

Tow-boat employed on the Yonne.

Length	25.00 m.
Width	5.00 »
Draught	0.900 »

Power of engine: 50 to 75 kilo on the pistons.

Usual load: 3 *flûtes* or *toues* of 38 m. and one of 30 m. forming a tonnage of 500 to 600 T.

Consumption of fuel: about 45 kilo per hour.

Speed ascending: about 5 km. per hour.

ANNEX III.

Towing by means of tugs on rivers.

Société anonyme des Messageries nationales (*b*).

This Company works the service of the Seine between Paris and Havre; its principal transport is wine.

Its plant consists of 4 tug-boats 4 tug cargo-boats, and 20 cargo-boats.

The tugs have up to 300 indicated horse-power.

The tug- cargo-boats have a tonnage of 300 T. and 200 horse-power. They are supplied with water ballast.

The cargo-boats are of various types, the largest are of iron, with a length of 55 m. and a tonnage of 750 T.

(*a*) Information furnished by the Administrateur délégué de la C^{ie}.

(*b*) Information furnished by M. Babin, Secrétaire du Conseil d'Administration de la Société.

Compagnie générale de navigation Hâvre-Paris-Lyon-Marseille (*a*).

Tug-boats on the Upper Seine from Paris to Montereau.

The company possesses two types of tug-boats:

1st *Type.*

Length	24 m. to 26 m.	1 Screw.
Width	4.20 m. to 5 m.	
Draught	1.800 m. to 2.200 m.	

Engine 130 to 170 indicated horse power.

Usual load ascending: 4 to 8 *flûtes* or *toues* (30 to 38 m.) according to the state of the water, forming a tonnage of 400 to 700 T.

Consumption of fuel 120 to 160 kilo per hour.

Speed ascending 3 to 6 km. per hour.

2nd *Type.*

Length	27.00 m.	2 Screws.
Width	5.00 m.	
Draught	2 m. to 2.200 m	

Usual load ascending: 4 *chalands* able to carry 800 to 1500 T. according to the state of the water.

Consumption of fuel 250 to 300 kilo per hour.

Speed ascending 3 to 6 km. per hour.

On the Upper Seine and on the Yonne convoys ascending are formed since mechanical traction has been introduced, *nez sur cul*, viz with the bows of the boats close against the stern of the one preceeding it and the first boat being about 50 m. from the tug.

Navigation on the Garonne (*b*).

On the upper part of the course of the Garonne boats are towed on the ascent and drift on the descent. Sometimes they are tugged as far as la Réole.

Between Castets and Bordeaux (54 km.) there are regular tug services; the tugs can draw as many as 20 to 25 boats. The descent is made monthly sailing or drifting. When the wind and the tide are favourable some boats ascend under sail.

The navigation plant in use on the Garonne may be divided in 4 types:

1st Ordinary boats for transport of merchandise.

2nd Steam-tugs.

3rd Steam cargo boats.

4th Steam passenger boats.

We will speak here of the two first classes only. The two others will be described in Annex IV.

(*a*) Information furnished by the Administrateur délégué de la Compagnie.

(*b*) Information furnished by M. Crahay de Franchimont Ingénieur en Chef, and MM. Sentilliès and Kauffmann, Ingénieurs des Ponts et Chaussées.

Ordinary boats.

They are keeled or flat-bottomed; and they navigate under sail, or with oars or are tugged. The principal types with their dimensions are given in the following table:

Names and types of the boats.	Ordinary dimensions.			Average tonnage.	Proportional part of each type.
	Length.	Width.	Depth.		
1st *Keel boats.*					
1. **Gabare**	16.00 m.	5.30 m.	1.80 m.	45	15 °/o.
2. **Sloop**	14.50 „	5.00 „	1.80 „	45	10 °/o.
3. Yole (called *de commission*)	9.00 „	2.50 „	1.10 „	45	5 °/o.
2nd *Flat-bottomed boats.*					
4. **Coureau**	18.00 „	5.50 „	1.80 „	55	15 °/o.
5. Cotrillon	25.00 „	5.00 „	2.00 „	145	15 °/o.
6. **Sapine** (open)	25.00 „	5.00 „	1.60 „	130	30 °/o.
7. **Poste** (decked)	25.00 „	5.00 „	1.60 „	90	10 °/o.
					100 °/o.

With the wind behind them the flat-bottomed boats make as much as 13 km. per hour with the stream and 5 km. against the stream; under the same conditions the keel boats have a less speed but they regain the advantage with a head wind.

The distance from Castets to Bordeaux (54 km.) takes from 5 to 24 hours according to circumstances. The journey on the ascent is generally much longer; but with the steam-tug it is made in 5 to 9 hours.

Steam-tugs.

Five steamboats are exclusively reserved for the tug service, but in case of need the same service is performed by cargo boats and other steamboats, belonging to private people or to dredging contractors or the service of public works; so that in time of pressure trade has at its disposal about 23 tugs worked by steam, of which 11 are with screws and 12 with wheels.

The boats which only serve as tugs are of iron. Their dimensions are very various, those of the paddle-wheel tugs are comprised within the following limits:

Length	28.00 m. to 64.00 m.
Width	4.30 „ „ 6.00 „
Draught	0.70 „ „ 1.60 „
Horse-power	20 to 80.

The figs. 1 and 2, Pl. III, represent two of these boats.

The *Gilbert* has a length of 64 m. and a horse-power of 160.

The *Amand-Dumeau* has a length of 55 m., a width of 6 m., draught of 0.70 m. and 800 horse-power.

The screw tug-boats are smaller (length 15 to 20 m.) and of less power (70 to 100 horse).

ANNEX IV.

Steam cargo boats and passenger boats.

Navigation on the Garonne (*a*).

Steam cargo boats. These boats carry merchandise; descending they serve as tugs to ordinary boats. Their hull is of iron. The paddle-wheels are placed aft and do not exceed the width of the hull so as to permit of their navigating the canals.

They are nine in number. They take 6 to 8 hours to ascend from Bordeaux to Castets (54 km.) and about 4 hours to descend.

Their dimensions are as follows:

Length	27.25 m. to 30.00 m.
Width	3.65 » » 5.40 »
Draught empty	0.60 » » 0.82 »
» loaded	1.20 » » 1.95 »
Indicated horse-power	20 to 30.
Average tonnage	80 tons.

Passenger boats.

On the Garonne above Bordeaux there are several passenger services extending from Bordeaux to Agen, to La Réole, to Castets and to Paillet. They are worked by the *Compagnie Gironde et Garonne.*

These boats are all of the same type; they are of iron, very long, not very wide, and are not deeper than 0.55 m. to 0.70 m. The engine is in the middle and governs directly the propelling wheels which are at the sides. These boats have two cabins for passengers, one fore and another aft. Passengers may also make use of the whole length of the deck, where chairs and benches are placed for their accomodation.

The dimensions and the power of these boats are nearly the same.

The length is from 52.80 m. to 62.60 m., the width from 3.70 m. to 4 m., the horse-power from 36 to 70 and the speed from 12 to 15 km. per hour. (See Pl. III, fig. 3).

Two boats more particularly devoted to the service of Agen, the *Lot et Garonne Nos 1 et 2* deserve special mention. They show in fact both in speed and arrangement very considerable progress.

(*a*) See above Annex III.

These boats, the dimensions and arrangements of which are similar, are built of iron and fitted with paddle wheels. N° 1 was put in service in 1890, and N° 2 in 1891.

They have the following dimensions: length 64.60 m., width 3 m. and a draught when loaded of 0.70 m. The hulls were constructed at the shops of M. **Labat**, *ingénieur constructeur* in Bordeaux.

The engines, on the compound system, with two boilers were made in the manufactory of M. **Sâtre** at Lyons. They have 320 horse-power and use exclusively Cardiff coal.

The speed of both the *Lot et Garonne* is superior to that of any other boats navigating above Bordeaux; it reaches 25 km. per hour. These high rates of speed, so favourable to facility of communication, are the cause of difficulties with respect to the preservation of the banks of the waterway, and they impose the necessity of serious precautions to obviate damage being occasioned to the ordinary traffic.

Formerly, the distance of 160 kilometres between Bordeaux and Agen took 13 hours in ascending and 11 hours descending; whereas now it does not take more than 8½ hours ascending and 7 hours descending, notwithstanding that the steamers have to serve 38 stations and that some delays are very long on account of the large quantity of merchandise loaded or discharged at certain important places.

These boats are comfortably fitted out; cabins fore and aft, a saloon and free deck, and can carry 500 passengers each.

The staff is composed of 1 master, 2 engineers, 4 stokers, 1 coaltrimmer, 1 clerk, 1 porter, 4 sailors and 1 boy.

A very active passenger service is worked in the neighbourhood of Bordeaux by small screw steamers (*gondoles* and *hirondelles*).

These boats are 15 to 23 metres in length, 3.20 to 5 metres in width, have a draught of 1.05 m. to 1.65 m. and a horse-power of 12 to 50.

Their speed averages 12 km. per hour; and they carry from 75 to 120 passengers.

ANNEX V.

Navigation on canals.

Société anonyme de navigation sur les canaux du Centre (*a*).

The Company works principally the lines from Paris to Roanne, from Paris to Lyons, through central France, and the Berry canal. Traction of boats is effected by animals, and in particular by donkeys.

(*a*) Information furnished by M. **Voland**, Directeur of the Company. The report which has been sent us by M. **Voland** also contains particulars of great interest concerning the origin and organisation of navigation on the ways of central France. We do not give them in this report, the object of which is absolutely special, but we hold them at the disposal of our colleagues.

The plant is on a small model as the water ways in use are not everywhere of the regulation dimensions. The boats are 30.50 m. in length, 5.05 m. in width; they draw 1.40 m. and can carry 150 tons. The Company possesses 240 of them. The speed is about 15 km. in 24 hours.

Canal latéral à la Loire (*b*).

The *berrichon* boats which constitute $^2/_3$ of the craft frequenting the canal are towed by their owner assisted by one or two donkeys and often by children.

Large boats are towed by two men alone or assisted by a donkey or a mule.

The speed of these boats varies between 1800 m. when loaded and 2500 m. when empty.

For a large boat carrying 150 tons of wood the price of the traction between Nevers and St. Mammés (208 km.), including the journey going loaded and returning empty, may be estimated at fr. 0.00466 per net kilometric ton, the freight being in general to fr. 0.017.

For the *berrichon* boats which carry only 65 to 80 tons the traction rates under the same conditions may be estimated at fr. 0.0051, the price of the freight being about 1 centime.

(*b*) Information furnished by M. MAZOYER, Ingénieur en chef des Ponts et Chaussées, and M. CLERY, Ingénieur des Ponts et Chaussées.

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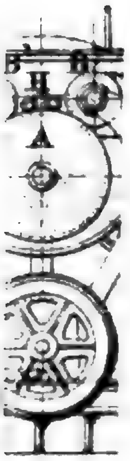
Hirsch & De Mas



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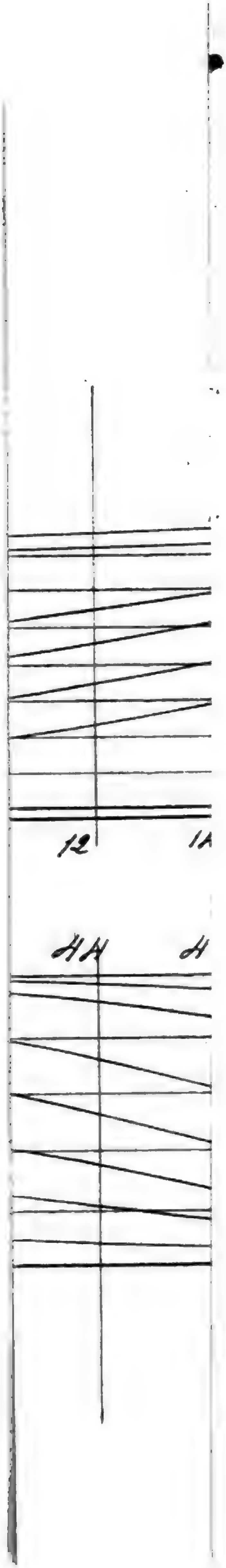
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PL. III

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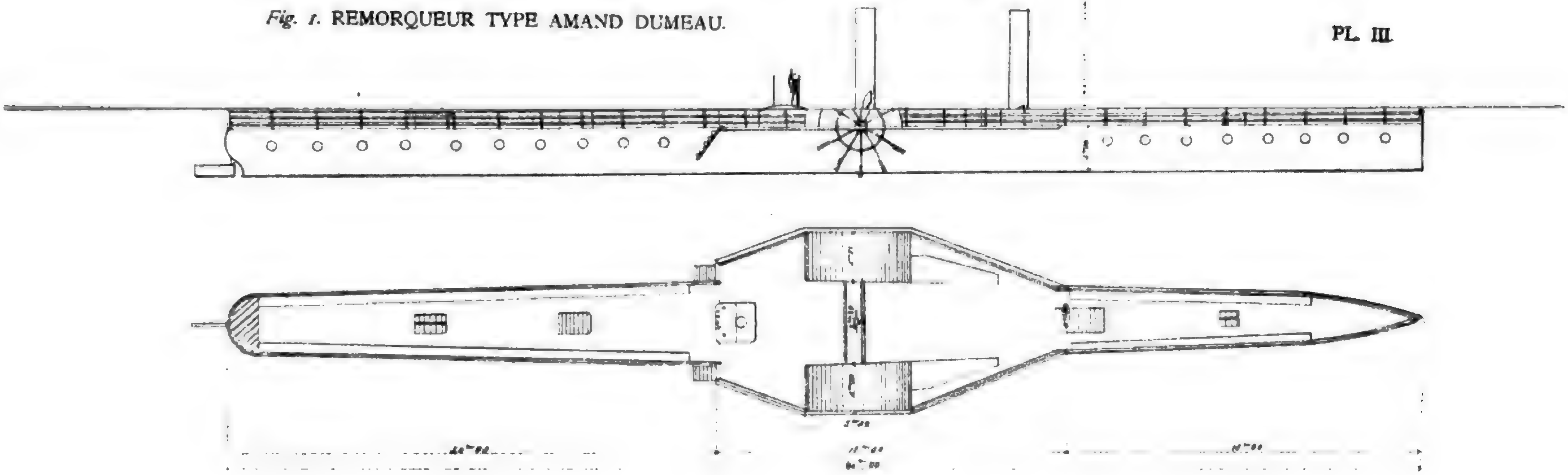

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STEENDRUKKERIJ v/h. AMAND.

RAPPORT DE
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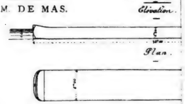

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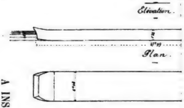

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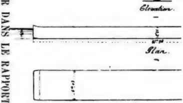
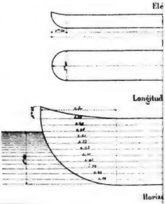


RAPPORT DE
M. DE MAS.

FORMES GÉOMÉTRI

TYP



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VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

4th QUESTION.

The method to organize different systems of traction on rivers, canals etc.

BY

MR. A. DE BOVET,
Director of the Traction-Society on the Lower-Seine and Oise.

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The method to organize different systems of traction on rivers, canals etc.

BY

M^r A. DE BOVET.

I.

Utility of canals and navigable rivers. They should be constructed at public cost. The intervention of the government in their management is right if the government can be of use.

In a very interesting report presented by Mr. DEROME at the Sixth International Congress by which he finished his study on the means of traction used on different canals in the north and east of France, he resumed as follows:

„The canals and canalized rivers are means of conveyance constructed „at public cost altogether for general use. It is a duty for the government „to manage them to obtain the greatest profit and at the same time „work them on the most economical system for commercial and manu„facturing enterprises."

We also said: that they have to be worked to the greatest interest of commercial and manufacturing purposes, but we can only take part in that idea on that special condition.

Conveyance by water or by railway. — Their competition.

The question of the true character of means of conveyance by water has often been and will still be discussed.

Some say that they are of good assistance for railways to convey ponderous goods of little value, which the railway companies are thought to be glad to get rid of. That way of considering the question is not easily accepted among the railway companies. Others believe that canals and rivers are above all competitors of railway lines, even for all sorts and all qualities of goods and provoke by that competition low freights that producers and consumers are the only benefitors.

Between these extremes there is place for different other opinions that most likely would be more true and all of them must naturally conclude that canals and navigable rivers are of the greatest utility.

It cannot be contested that trucks and boats can be used for all kinds of merchandise.

In practice, where both means of conveyance exist, a sort of classification takes place, heavy goods wanting low freight, that manufacturers receive by great quantities and which are not urgent go generally by water, others by rail.

It is simply a commercial question for which there can be no question of regulations and it would be even difficult to classify as there would be too many sorts of goods that it would be difficult to class and these would be the special object of competition between the two means of conveyance.

Taking another point of view we believe that it is impossible that canal and railway would not compete if they have the same direction and distance but on the other hand if the one or the other be the continuation, the interest would be mutual. But generally the parts of a country where canals or rivers exist that will also be the centre of commercial and manufacturing undertakings and the spot of the greatest trafic, subsequently the places where most important railway lines will be run.

We believe that for this reason a canal and a railway line will always be rivals. In certain countries they agree and we think they are quite right; but in other they simply submit and we could point out different railway lines who do their best to hinder as much as possible the loading of goods from truck to boat and vice versa. This does not mean that they act in their own interest.

Character and consequences of the composition between railway and shipping lines.

We have already said that this competition falls especially on goods of a certain kind which must be conveyed at lowest possible rates otherwise it would be found that they are not worth the carriage; they are of more consequence in bulk than in receipt of freight.

It cannot therefore be said that this freight is altogether taken from the railway line as a part of this trafic would not exist if it had to be carried by railway.

The prejudice done to the railway can also be disputed for another reason; this prejudice does not exist as long as the trafic gives no profit to the railway company.

On the other hand it cannot be contested that a great development of a manufacturing region which is well served by both means of conveyance, all honour is due to the boating for its prosperity. This prosperity does not take place without a great development of all kinds of trafic and all sorts of goods. If the shipping conveys more and more the rough material the railways do the same with the manufactured article; the first part does not increase without increasing the second and it cannot be a disadvantage for the railway if it loses on one side the rough material at low freights to gain a more finished article at high rates. For instance in France the Compagnie du Nord is more than any other line in rivalry with many canals and rivers of great trafic and that is the only Company who has not to ask the guarantee of the government. Among all the lines of the Compagnie de l'Ouest, the one running from Paris to the Havre, parallel to the Seine on its whole length, is we believe the one that renders the greatest profit. These are substantial proofs.

We will take another example of a different nature. It is easy in consulting a map to see that the valley of the Rhone prolonged by the valley of the Doubs and Saône form means of conveyance between the Mediterranean and all central Europe on the north of the Alps.

The difficulty of navigation on the Rhone has not been resolved up to the present, but as soon the question will be successfully cleared it is to be hoped that the trafic will be much greater than before. The P. L. M. Company will perhaps loose a certain quantity of goods that it transports actually, but will it not regain the loss and perhaps more by the increase of another kind and quality of goods? On our part the answer is without doubt and it is therefore that we have already said that all profits can be combined in the competition of truck and boat.

The influence of shipping by canal or river has the effect of developing the commercial activity in the region where it passes on account of certain low rates. But the class of goods that can be conveyed by water to profit of the low freight are undetermined; the interest of the railway Companies is to diminish freights as much as possible, which they try to do in reducing their taxes for all goods in the badly determined limit that we have shown.

In practice these reductions extend to other goods and other railway-lines by a sort of attraction and also before the impossibility of continually maintaining great differences between tarifs existing on other lines of the Company. That influence of canals on railway freights has often been pointed out; it is of the highest importance and justifies sufficiently the part that is allowed to canals and rivers in the development and prosperity of a country.

Water courses being made of public cost the government has the right to take part in their management.

In order that these means of conveyance can be productful to their utmost and allow freights which permit the greatest extension it has been shown by practice that no taxes or other such sums must be received in order to cover the cost of constructing or keeping in repair. The costs that the goods should support are: loading, discharging, towing, rent of the boats and salary of the creed. The consequence is that the cost of the establishing of canals ad improvement of rivers should be supported by the government; this is done nearly in all countries although different economical managements may exist. In Germany and Belgium the government has also the management of the railways and subsequently it becomes its own competitor in the management of canals and rivers. In France also because the government guarantees a minimum of revenue to all Railway Companies, and in the United States of America where a part of public revenue is employed to help private undertakings. Mr. Bogart in his report to the 6th International Congress pointed out that public interest still finds its profit in this way.

This system of management has been contested and it has been claimed that the capital used for the development of canals and rivers should be employed in a more profitable manner by giving these sums to the Railway Companies to enable them to reduce their tarifs to the limits of those existing on canals; also that railway lines escape nearly altogether from the accidental causes of non employment (ice, floods etc) and represent a material much more perfect that can suffice amply to all wants, therefore it is not necessary to have other means of conveyance.

We do not believe this and we satisfy ourselves in asking how that limit would be fixed if the canal is no more there to impose its freights and in which measure the government and its agents could appreciate exactly the limit of the cost price and profits of a manufacturer.

We believe the usual action of the Government in constructing canals and canalized rivers quite useful and justified, however under the condition the government will simply restraint its power to the natural conditions of the different parts of the country; the sacrifices that are imposed on the public treasury being useful to all and subsequently of great profit to the country.

In fact if the canals do not cover all their expenses of existence and management as a railway line can do, it does not mean that these are not paid indirectly and even largely covered by the extension it gives to the activity in the manufactures.

If this is so, it is natural that their building comes under the same item of public cost as the roads do, which cost must be made to enable the country to progress in value; these canals are in reality „artificial roads constructed at public cost for general utility and the conclusion that they should be worked" in the best interest of manufacturing and commercial profit should be a first condition.

Remark on the measure in which it would be right to develope means of conveyance.

All what has been said makes one suppose that the facility and small cost of transport is a good thing; it is true that men far back in history considered good means of conveyance as a first necessity, not only for war purposes but also for mutual exchange of products.

To procure these they did not draw back before any amount of trouble and pains which these works gave them and that proves the great importance they attributed to these roads. It is only untill a recent date after having perfected slowly the means that they possessed since many centuries that the steampower and its use in navigation and transport by rail came suddenly to the help of the means of conveyance and brought them far ahead. In a few years the world has become small if one measures the time and distance that is wanted to travel over it; but in the same measure the lands accessible to be cultivated have also considerably increased and as the value of each thing is regulated by the abundance and penury of offer and demand, the preceding stability was altogether overthrown.

The threatened interests have naturally been forced to defend themselves; the necessity was evident, and the choice of the means used, have, as always in those cases, been the object of criticise that still exists. The great facility and the low cost of conveyance renders the buying of foreign products at far off markets possible and selling home made goods by the same way; the result is a reduction in general of cost prices and permits a country to buy, sell, consume or manufacture larger quantities of goods.

For some the consequences were unavoidable; wisdom consisted in accepting them openly and to procure the implements necessary to the extension given to manufacture and commerce.

Others, more particularly struck by the overthrow and threatened in their position by the transformation in the manner of transport, thought it necessary to find a guarantee in customs-duty, not in the idea to fill the public treasury or to sustain the establishing of the new transformations, but simply to work against the invasion of their market by foreign products.

The first system pushes to the extension of commercial interchange and profits of all things by which it can be favoured and especially requires cheap and powerful means of conveyance.

The second, revokes the result that it would be possible to expect from the extension of the provision market and maintains prices of all things above their real value; it restraints on the contrary the qauntity of goods that the manufacturers could produce with their implements, diminishes greatly the interchange and subsequently the transport for which it is then not necessary to construct means of conveyance above the limited wants.

We must remark that in that case the utility of searching a maximum of capacity and a minimum of freight in a country which is imposed by laws that kills its effects forms a literal economical incomprehension. If the direct interference of the government may become necessary for the establishing of certain means of conveyance, that interposition must produce itself in a measure that accords with the accepted commercial management and which may have chance of being kept by the country.

For our part, we cannot believe that men who have improved the relationship with other countries will renounce to profit of their success. In any case we wish plainly to state and point out what we have already said of the „artificial means of conveyance constructed at the cost of the country" must be those that are in reality established for public use, that is were there useful effects must not be artificially diminished or destroyed.

II.

It is sometimes necessary to monopolize the different towing services.

If it be admitted that artificial means of navigation must be managed in commercial and manufacturing interests, it has to be said how that desirable result can be arrived at.

The working of canals and canalized rivers admits the existence of means of towing at the disposal of all boatmen.

The traction of boats is done by tugs, kedgers or horses. Towing by horses is actually exclusively limited to the traction on canals and all is done to substitute in their place, steam power. It is quite clear that the traction implements (we will comprise horses untill they will be replaced by something else) by their high value and special hand labor has more worth than the boating material and one must be separated from the other to enable the towage to continue work in order to reduce the cost price.

In that point we find that a steamboat for interior navigation is quite a wrong thing and could be compared to a railway engine clinched to the train.

Beside that reason of separation between the vehicule and its moving power which are alike for both means of conveyance, there is still another and great difference. It is a practical necessity that the truck which is expensive relatively to its small loading capacity must belong to the railway companies; there are only a few cases that the trucks belong to the sender.

It is not the same on water. A barge, for instance, is really a cheap thing (about £ 400) instead of £ 6000.— that thirty trucks would cost to carry the same quantity. Each boat wants at least one man (one man suffices on canals, but generally two are wanted on rivers) independantly of the steam power that moves it. Its mode of circulation ressembles to the road vehicules where it is not necessary that the horses belong to the same proprietor as the coach; before the invention of railways the system of relays was found very advantageous. It is therefore not necessary that the barge and the propelling power belong to the same undertaker; the boat can, such is generally the case in France belong to the man who directs it.

With a small capital, as barges are not expensive, the boatman becomes a sort of undertaker if he finds everywhere means of going foreward.

It can be presumed that the annual cost, keeping in repair, amortization etc of a barge, will amount to a higher sum if it be in the hand of a company who pays the wages to the boatmen, than if the barge is directed by its proprietor. As to the question of finding the goods to transport if this costs more to a separate boatman it would not be difficult to form an association. Undoubtedly Companies can be formed who possess not only the barges but also the steam power and nothing should be done to impede the working of any arrangement in that way.

But if it be admitted that there is a great advantage to favor or at least to facilitate any private enterprise of one individual man he must at least find means of traction wherever he goes without being forced to pass through the hands of a Company of conveyance who being a rival would think more of competing than of giving aid. It may happen that there exists a Company having implements of traction who lets its help to all boats in general; that would be the best organization to arrange all interests.

The principal thing is that all private boatmen can always find means of being towed and not be obliged of doing so himself.

How must the service of traction be organized?

We have already explained which are actually the means of traction employed; we do not intend to study the technical point but simply examine the question as to the most profitable way of using these.

Rivers and canals.

It is easy to comprehend that the management of a river is different to the management of a canal. The first may be simply made regular by embankments or canalized; in both cases they are apt to have large sluices who can receive one or several boats at once. It can be compared to a road allowing vehicules which go fast or slow in one direction or the other without being hindered and not be obliged to change the speed.

A canal is on the contrary generally of small width, the sluices are small and numerous; it is a path were the pace of one cannot but be an hinderance to the other, and there must be a constant attention to stop obstructions or accidents, consequently a strict and even severe regulation at certain places. There are cases, for instance at the reaches, or else where the canal leads through a tunnel where it is impossible for two boats to pass one another.

Particular points on canals. The towage is compulsively monopolized.

We must first consider the above particular case. The passage being impossible it is evident that special hours be observed for the boats going one way and the same thing for the other direction. Now supposing that there is considerable trafic on the canal and that the boats arrive at the limit or near the limit of circulation it will not suffice to allow periods of time for going in one direction or the other but it would be necessary to oblige those that are at the reach to make place for the new arrivals.

The undertaking of traction in such cases must be monopolized and effectively it is so. We will give as example the towage done by the French Government at the reaches of separation on the canal of S^t. Quentin, the canal from the Marne to the Rhine, the canal of Bourgogne. Generally the idea of monopole encounters in France general reprobation and no one thinks that in this particular case it could not be done otherwise. To counterbalance the inconveniences that are generally put forward there are great advantages, to make a maximum use of the canal is not the only one, but also the advantage of the low prices for the services rendered. We refer as proof to the information given by M^r. DEROME in the raport that we have already spoken of, on the traction in the reach of reparation on the canal S^t. Quentin.

Although the prices given are quite correct one must not take them as basis before examining them. The reason is that generally in operations of that kind done by Officials of the Government many expenses and charges are not counted notwithstanding that they exist in reality and would of course be reckoned if it were a private undertaking. These expenses are: general costs, salaries of agents paid by other revenues; interests and sinking-fund, taxes of all nature etc. But still if a coefficient is added to correct these, the price remains still very low.

Canals of great trafic. The monopoly imposes itself.

The difficulties arising from the narrow width are not limited to the few sections that we have just noted where they are important, they are also met on the whole way of a canal if there is considerable trafic. In the management of these canals there are two points to be considered. 1^0. The use of the canal; 2^0. the use of the material.

To make a profitable use of a canal it is necessary that all the trafic is managed in such a way that at any point of encumbrance the maximum of outlet is kep. The working of a canal depends entirely upon the sluices (the speed is quite independant); as perfect as sluices may be the boatman must not take more time than is strictly necessary to effect the passage of a sluice as he might do if he is idle and careless. A strict regulation is necessary and right to enable a continual and profitable use that could be hindered by the indolence of a few. The profitable use of the working stock is denoted by the number of voyages done during the course of a year; that depends therefore partly on the speed. It is also to be noted that the more voyages are made the more the freight for each voyage can be reduced and greater the trafic.

The points to be attained are clear: at the sluices a service to enable quick passages; on the way a speed that the sluices do not stop work while others be encumbered; and the speed regulated to realize an economy on the traction. It is to be supposed that this can never be realized if each boatman chooses his own system of traction and the result is that the means of traction should be monopolized. We will give as example the canal of S^t. Quentin and others of that region where great trafic is continual and where after many different essays, the service ot traction has been granted by lots to different undertakers who have the monopoly.

One of the results is, low prices and not so expensive as on the lateral canal of the Oise to the Oise where trafic is quite as considerable and where the boatmen have more choice in their means of traction.

Evidently it is on account of the regular service that these low prices exist and that the loads be of some consequence. On canals where trafic is not so great and where sluices work only occasionally it can be allowed that boatman find their own means of traction, for instance horses that they own or else that the inhabitants of the region procure them; but it is to be supposed that any canal has actually or will have in future sufficient trafic, otherwise its construction is not justified.

Traction bij steam power. It is to be foreseen that its realisatfon will necessitate monopoly.

We will suppose that the problem of the traction by steampower on canals will be satisfactorily realized in future. The result, whatever it may be, must enable the separate traction of boats who would have to pass separately through sluices; it must admit in an undetermined way, the distribution ot a certain amount of work among the different crafts all along the canal and will necessitate high cost of establishing. Mr. M. Levy valued the cost of a funiculary installation at 20 to 25000 francs per Kilometre (1270 to 1580 £ per mile) and it is to be supposed that it would be impossible to reduce that estimation.

The application can only be tried on canals with great trafic; and even on such canals the cost of the management which would have to be added to the heavy cost of establishment could most likely only allow a price sufficiently low on the condition that the whole trafic pass through their hands.

We believe also that on other terms no capital could be found for such an operation. Another reason, for instance if the propelling power had to use the lowing path it would be impossible to allow horses use the same path or if the establishment of the installment of steam power would be too heavy if it would be necessary to leave the towing-path free.

Some systems among those known have lead to a monopoly by their insuccessful results and even to precise regulations for their working; for instance, the system of Mr. MAURICE LEVY by which the boats going one way must alternatively take at the reaches the ties of even or uneven numbers and if they do not do so they desorganize the whole service. Others do not impose to the boatmen such strict obligations. But we do not think that any will succeed if they have not the monopoly.

To resume, we find that it is necessary to monopolize the means of traction.

Canalized rivers. The monopoly of traction is not necessary to the same degree as on canals although it may be sometimes of use.

If we pass to rivers the cases differ.

The width of the water gives a facility of movement and will permit different modes of towage to exist. It is interesting to examine how in practice the management is done and we will take an example best known to us. It is well understood that if we take this particular example it is to enable us to give a clear exposure. We speak of the Seine.

Up to 1860 the system employed was a towage against which the few tugs existing could not compete with success. The river had then a small draught and a rather strong current. The organization of the towage had the great advantage for the boatmen to furnish at all time necessary traction at small cost.

As it is quite impossible to dispose several chains belonging to different undertakers, the right of placing one had to be granted on the presenting of a bill of costs. Those determined did foresee a fixed tarif which could not be changed without the consent of the manager entrusted with the survey, similarly to railway companies in exchange for the monopoly assumed. This was quite natural as the companies of towage had the monopoly on account of the superiority of the system of traction employed if they had not this monopoly by right. The adopted prices were low in winter, higher in summer on account of the services rendered, but with the monopoly the compensation existed from one season to the other; these prices represented a reduction of 60 pct. on the preceding ones and had the great and important advantage for the conveyance to be of great fixity.

Since then the finishing of the canalization has quite changed the regime.

During a great part of the year the current is so slow that it hardly exists, even that the boats going with the current have to be towed which precedingly was not necessary. The kedgers as they are actually constructed do not favor this operation. On the contrary, tugs have that great advantage that with the greater draught and the progress made in their mechanical construction allow them to compete with succes even during a long period of water. But with high water when the barriers are down and the river takes its natural run, the kedgers regain an advantage which is so marked that according to general idea if they did not exist the boatmen would be badly served and prices become excessive. Under these circumstances the two modes of traction are practised and during the wet season is profitable to one and to the other during summer; that regime of competition would evidently be insupportable if one system would be worked on fixed tarifs while the other kept its entire independance.

The undertaking of towing being quite free, the preceding bill of costs had to be modified in order to establish an impartial proportion between the value of the grant and its obligations.

The fixed tariff has been replaced by a tariff maximum below which all liberty is accorded to the companies of traction; this tariff is a guarantee for the bargement against excessive prices during the lapse of time during which traction is difficult. The necessity of this transformation was necessary and has begun a new regime likely to continue; what are it consequences with regard to the users of the different modes of traction?

In the actual condition of the Seine, it can be admitted that to ensure a regular trafic it would be necessary to use in winter twice as many kedgers and four to four and half as many tugs as in summer, the ability of both being valued according to their respective power. Kedging seems to have the advantage on tugs to realize a middling price, but that is only true if the trafic is of great importance.

To establish a kedging service necessitates great cost; it is therefore not possible to proportionate the general cost to the quantity of boats towed at the same degree as for a service of tugs. It is the same thing with all undertakings necessitating heavy cost, the more production of work there is, the more the cost price is reduced.

In this case each mode of traction having during a part of the year a favorable period is obliged to profit of that time to attenuate the loss that the other period has brought in, and it easily understood that each a regime is not the way to obtain the realisation of low prices.

In practice it is indubitable that average prices of traction on the Seine are lower now than 25 or 30 years ago, but the reduction is not in proportion with the importance of the works that have been done.

But if instead of taking the average prices we take the extreme prices it will be seen that winter prices are high and the maxmum fixed by the bill of costs of the towage undertakings higher for strong currents than those fixed a few years ago.

The canalization of the river has bettered the average regime, but has on the contrary exagerated the difference between the extremes. The regime of prices has differed in the same sense as the regime of the river; they have become during the successive periods of the year, more unequal than precedingly and that cannot be a favorable condition for the developement of undertaking of conveyance by water.

We have taken this particular example to show more easily difficulties that can be met on a river for the services of traction.

Without studying further this case, we will retain this, that the more corrections are brought to the natural regime of a river, the average conditions will be bettered but the extreme prices prices will be more consequent and greater the difference in the terms on which the traction of the boats will take place; the effect will of course be greater on canalized rivers than on those simply made regular, the costs of the work on the first having been greater than those on the second. It can be understood that in certain cases the trafic would not be so important and that an undertaking who by its monopoly could reduce and guarantee fixed prises would be a good thing.

There must be no abuse made of this remedy and we believe that it would be more rarely used on rivers than on canals; but we wished to show that it could be right to do so.

We will conclude in saying that on canals and sometimes on canalized rivers it is right to constitute monopoles of traction if it be proved that it is for the development of the trafic; obtain a good and regular use of the water courses; fix low prices and not refuse a monopoly if it can be of real use.

The undertakings of traction must be obligatory only for boatmen or companies of traction who have not themselves means of conveyance.

III.

The towage must be intrusted to private undertakings.

In general the government must not take charge of undertakings having an individual character.

We admit that in certain cases it is right to monopolize the means of traction on canals and rivers for the totality or determined classes of boats to make use of them. The monopolies must they be managed by the government or by private individuals?

We do not hesitate to pronounce ourselves for the second solution, thinking that there is greater advantage to leave this right to private industry and that there is nothing more hurtful than the intervening of official management.

In this case the question is not to receive taxes and we believe that governments are but middling transactors; in different countries the governments have tried and still try to do so but the results obtained are not of nature to change our idea.

It is not necessary to say that if this is true the cause must not be found amidst the servitors employed. The real and principal cause of this inferiority in management is in the nature of control with which the operations are undertaken. There is evidently a great difference between a government spending the income provided by obligatory taxes and a direction of a private company who tries to make the most of the sums brought voluntarily by the persons interested.

Every one contributes to fill the public treasury and each individual thinks that he has a right to its contents and he tries to realise them to his own interests in the form of pensions and salaries or other works; the result is that the government has never ressources enough to cover all sollicitations and still it has to regulate the spending of funds in order to respect all true pretentions brought forward; it creates functions to form an administrative organisation, but generally it has to submit to agents who have access to the vacancies according to certain rules and as it has to give a guarantee that all sums go to the end proposed, the necessity is shown of an enormous complication in the administration and a control according to strict regulations. This control must as much as possible repose on precise and not on facts subject to doubt.

But such an organisation cannot be applied to any new undertaking that can bring in misreckonings. This is the case for the undertakings we are now studying, which are naturally under the law of constant transformations and of which the result is doubtful.

To resume the governement has to submit unavoidably to organisations which tie its agents to narrow rules paralysing all idea of a right to making innovations. In general the undertakings that a governement has no right to take charge of, are easily explained. They are these of general utility for which costs are necessary that cannot be entirely retributed. It can execute them or else have them done by undertakers at the lowest possible price. As an example of undertakings of this kind we will cite the construction of canals and the canalisation of rivers if taxes must not be imposed to pay back the cost of their construction.

On the contrary for each undertaking that can realise a profit, the government can easily find private enterprises who would feel disposed to substitute themselves in its place and such a substitution can only but be advantageous.

If the government can only receive sums and spend them without id a of profit, private undertakings will find the greatest stimulant in the gain being sure and the expenses covered. By their system of management these have a greater liberty of action.

The choice of their factors to whom they intrust the care of their operations is dictated by the security they inspire, they are not imposed by regulations or by competition, which is respectable, or else by political views, which is less worthy of respect.

These agents having no public power cannot be tempted to replace sometimes a bad reason by an act of authority against which all recourse is very difficult.

Their authority is not paralysed at every moment by street regulations and the obligation to apply a formulary which is often as complicated for small operations as for important works.

Being trusted by their masters they can accept the responsability of their acts, the appreciation of which will not be submitted to a system of suspecious control.

Under these conditions a new undertaking can produce itself with more chance, the useful effect of each individual will be as great as possible, the work done cheaper and more surely and it is for these reasons that we think it right for the government not to undertake any enterprise that can be done by private industry.

If the traction is given in monopoly, the government must simply form a bill of costs and survey the undertaking.

The motives that we have brought forward in that idea are general but they still exist for the special case we have in view. The government can manage canals and rivers as it does for railways. But for that undertaking must exist a tariff of fixed prices, well defined. It is difficult to understand how it could apply by its agents the regime of the new bill of costs of the Company of Towage on the Seine, which gives the faculty, under a fixed maximum to follow all the fluctuations of the prices of traction that exist according to the state of the water and the competition of other towage enterprises.

Even with that reserve we believe that such an enterprise would have all probability of being better managed by others than by the government and of being successful.

We have had the occasion to signal the application of a service of towage in France by factors of the government divided in subterranean reaches. We do not see the advantage of having such agents besides the one of being empowered by police regulations to assure the circulation at places particularly encumbered. Taken at a technical point of view their ways of working are exactly those chosen everywhere by private undertakings to whom are due all improvements made in the machinery used for the traction of boats.

We must make an exception for the recent application happily realized by a distinguished engineer on the canal of Bourgogne to promote the using of electricity as is employed for the running of tramways. Should we make a mistake in pointing out this as an example how a strong will can conquer difficulties?

The experiments of funiculary traction made by Mr. MAURICE LEVY at governmental cost can also be noted especially as an exception isolated among so many essays made in the same way by private undertakings.

On the other hand we must state that the government having executed considerable and costly improvements on the Rhone, the result being a progress in the regime of the river, had to leave in a state of uncertainty the question, still undecided, to know if the burying of the chain of towage will still have to be feared as before. The question is nothwithstanding interesting as the trafic could be of great importance, but the current is so strong that it is impracticable for tugs or too costly. But the government had allowed the credit for the accomplishment of works and not for essays.

We believe therefore that in certain cases, the traction must be monopolized by private industry, the role of the government should be limited to the establishing of the bill of costs that has to be imposed for the grantee and also the survey of its execution.

Conditions to be applied in the bill of costs.

The true aim of the bills of costs is to guarantee the public against possible frauds on the part of the grantees that is to say insufficient service or too high prices. On the other hand the recourse to a grantee is that the public should benefit of the efforts that he will make to a lawful profit. It is therefore necessary that the bill of costs be calculated in order to allow such profits.

Experience proves that the government can find undertakers who accept strict clauses enabling but limited gains. We do not think that to abuse of this facility shows good management; that cannot be the way to obtain a good execution of the operations transmitted, or the system to avoid fraud or incorrections.

The other system that guarantees an interest to mitigate conditions that at first sight seem too burdensome to be accepted without some compensation should also be avoided as much as possible as it disinterests the grantee to accomplish possible improvements and stops the principal stimulant: the allurement of a possible profit. Also, if the imposed conditions are too large or assure a large profit, the same inconvenient exists.

In one or the other case, the different cause produce similar effect as that of a manufacturer who has no competition on account of protection by customs duties, and remains therefore in a state of indolence and stagnation. The desideratum should be that the conditions imposed leave a marge of possible profit sufficiently ensured to tempt those who desire to work honestly. An error to the advantage of the profits is better than for less, because the remedy is easily obtained; that is that above a certain quantum the grantee would pay back a part of the profits in proportion to the continued gain, but still that there be sufficiently left to search new improvements.

These retakings could be done by a system of reduction of tariff, in that way the conveyors and tractionners would both be interested in the improvements realized.

These profits could be affected to the improvements made on the river or canal as it is right that the traction undertaker co-operates when the circumstances do permit these improvements as that is a good way for them to increase their trafic.

The toll question has been longly discussed. For some they should not exist under any form and should be completely suppressed. For others special tolls should be received for the improvement in detail of certain works.

Besides cases allowing such kind of transactions will only interest a limited number of employers that means that hitherto the government has taken over all the expenses for the putting of the water courses in their present condition but that in future the boatmen will have to share in the cost of ulterior improvements. One of the reasons which most likely does not allow the coming to an agreement is the difficulty felt in indicating the exact point which would allow the going over from one regime to another. If this is the case, the reason is doubtless that these water couses have already attained a very high degree of perfection or that they are not at present of any known utility.

On our part we are convinced that on important canals or rivers a monopoly of the service of traction can give important profits with low prices and we think that a part of the profits could be allowed to works of improvement and this system would be better than fixing special tolls to that end.

There is a certain lien between the correction of works of art and the possible price of towage; the perception of such a tax would be very easy as it would be necessary to make the boatman pay the sums that the is used to.

We know that to make a correct bill of costs is not always easy, but still we do not think it impossible. Their efficacity is only sure if they are closely surveyed. Errors can always be committed; and those errors made during the application of any system do not prove anything against its value.

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4th QUESTION.

Traction and propulsion upon canals, canalized rivers and rivers of natural flow.

BY

E. H. STIELTJES,
Civil Engineer.

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Traction and propulsion upon canals, canalized rivers and rivers of natural flow.

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The programme fixed for the study of the question of the better economical organisation of traction on navigable ways is the following: „*Progress realised since the previous congress in the application of various systems of traction and of propulsion of boats. New systems since invented or applied. Influence of the form of boats and of the condition of their surface on the resistance to traction. Speed necessary and realisable for cargo-boats, tug-boats and tow-boats with their trains*".

If we confine ourselves absolutely to a report on the various points of this programme, the reply to the question in so far as it regards the Netherlands could be made in very few words. There is no realised progress and there are no new systems to mention. Dutch engineers follow with the greatest interest the remarkable experiments in funicular traction according to the system of Mr. LEVY, and of traction by locomotive, especially made in France and also in Germany, as well as the experiments in electrical towage according to the systems of Mr. DE BOVET and of Mr. GAILLOT. They are convinced of the extreme importance of the experimental researches of Mr. CAMÉRÉ and of Mr. DE MAS on the influence of the dimensions of the section of the navigable way and on the material of navigation, but up to the present no analogous experiments have been made in Holland.

Besides, the tariffs for towing or tugging, and the cost of traction which might be quoted are so varied, and so doubtful that they possess no interest in the study of the question of the better economical organisation of traction on navigable ways.

If, notwithstanding, I have undertaken without hesitation to give some observations on the question of traction and propulsion on canals and rivers, with regard to the Netherlands, it is only because I am convinced that this complicated and difficult question is not susceptible of a general solution, and that it is neccessary to seek out for each country, or rather for each basin of commerce and navigation, systems, which will best agree with local requirements and the exigencies of the working of the navigation way in all its extent.

In the Netherlands, especially, the condition of the rivers and canals is of a peculiar character, and differs, for example, very much from that of rivers and canals in France.

Let us take a rapid glance at the navigable ways in the Netherlands and at the means employed for traction and propulsion.

I. THE NAVIGABLE WAYS IN THE NETHERLANDS AND THEIR TRAFFIC.

The navigable ways of the Netherlands consist of the lower courses of the Rhine, the Maas and the Schelde with their arms and junctions, of the Zuiderzee and an extended net of canals, which join the rivers or the Zuiderzee.

The rivers.

The Rhine and the Schelde, but in the first place the Rhine are the principal ways of traffic in Holland. In 1892 38174 boats passed the frontier near Lobith, that is 29849 boats sailing or tugged, 925 cargo steamers, 6219 tags and 1181 passenger steamers. The tonnage of the 30774 sailing and cargo boats was 9155496 cubic meters; the average tonnage of the sailers 295, that of the cargo boats 378 cubic meters.

The commercial movement on the Rhine increases every year, corresponding to the improvements, which have been carried out on this river, and with the developement of commerce in the ports, consequent on the facilities for entering now granted.

In Germany the object of the works of improvement is to give to the channel of the Rhine from Mannheim to Saint-Goar a depth of 2 m. and from Saint-Goar to Cologne of 2.50 m., and below Cologne of 3 m. at the low ebb of 1.50 by the Cologne scale. In the Netherlands endeavours are made on the Waal to obtain a depth of 3 m. and for the lower Rhine and the Lek above Vreeswijk a depth of 2 m. at the ebb above-named.

Works recently commenced and now in course of construction will give a depth of 2.70 m. to the Waal, and last year the legislative power voted the necessary works for assuring the desired depth to the lower Rhine and the Lek.

The Yssel in Gelderland, the branch of the Rhine which flows into the Zuiderzee has not a great depth and at ebb tide allows a passage only to boats of a draft of at most one meter. Nor, does the Maas possess a sufficient depth above the St. Andries lock (between Waal and the Maas).

On the contrary, the rivers and the arms of the sea in the provinces of South Holland and of Zeeland have in some parts a considerable depth and allow of an uninterrupted fluvial navigation. Thanks to successive improvements in the river the dimensions of boats navigating the Rhine have been much enlarged.

In 1878 the largest boat was of a capacity of 850 tons and there were only 9 boats with a capacity exceeding 650 tons. At the present day there are a large number of boats of 800 to 1000 and several of 1200 to 1300 tons; of some the capacity amounts even to 1500 tons. The largest dimensions are: length 85 to 90 m., including the bowsprit and the rudder, width 10.50 m., and draft of water when fully loaded 2.70 m.

The major part of the exterior traffic, which passes the German frontier follows the Waal. It is directed principally towards Rotterdam, Dordrecht and partly towards Amsterdam (by the canal from Gorinchem to Amsterdam) and towards Belgium by the Hollandsche Diep, the rivers of Zeeland and the canal through South-Beveland.

Another part passes by way of the lower Rhine and the Lek towards Arnhem, Utrecht, Amsterdam etc., or by way of the Yssel.

Official statistics give the following figures for goods entering and leaving at Lobith in tons of 1000 kgr.

	Goods entering.		Goods leaving.		TOTAL.	
	1892.	**1893.**	**1892.**	**1893.**	**1892.**	**1893.**
Rotterdam . . .	537601	537979	2123894	2752070	2661495	3290049
Amsterdam. . .	104926	88547	106814	111139	211740	199686
Dordrecht . . .	71854	94709	112126	83732	183980	178441
Various ports. .	1684846	1655321	123788	99925	1808634	1755246
Belgian ports . .	665908	552500	781107	757533	1447015	1310083
	3065135	2929056	3247729	3804399	6312864	6733455

The table shows that many boats which on entering brought goods for various ports, on leaving carried their cargo from Rotterdam.

In addition to this traffic there exists on the Rhine and its branches and on the rivers of the provinces of South-Holland and Zeeland a very intense movement of inland navigation between the various provinces of the kingdom and between the Netherlands and Belgium. Statistics of this traffic are wanting, as are, also those of navigation of the Rhine between the branches of this river. To give some idea we may quote the following figures:

In 1892, 18473 boats of a tonnage of 1416889 cubic metres, among which 4469 steamers of a tonnage of 335265 cubic metres passed the floating bridge on the lower Rhine at Arnhem; 17135 boats of a tonnage of 1584440 of which 5651 steamers of a tonnage of 531247 cubic meters passed the floating bridge on the Lek below Vreeswijk.

The IJssel in Gelderland at Westervoort had in 1892 a traffic of 10836 boats, of which 2746 were steamers, and the mouth of the Zuiderzee was passed by 7277 boats, 3370 steamers 17 sea-going ships and 12852 fishing boats.

The South-Beveland canal which, forms part of the principal way for inland navigation towards Belgium, was traversed by 32763 river boats of a tonnage of 3468696 cubic meters.

The canals.

The number of navigable canals amount to about 240, with a total length in round figures of 3400 Km. About 1550 km. are in the provinces of Friesland and Groningen, 400 km. in the provinces of Drente and Overijssel, and more than 1000 km. in the provinces of Holland (North and South) and of Utrecht.

a. Maritime Canals.

Some of these canals have been constructed for maritime navigation. These are: 1°. *The North Sea canal* from Amsterdam to IJmuiden (length 27 km., depth of water 7.70 m.); 2°. *The Great North Holland canal*, from Amsterdam to Nieuwediep (length 80.4 km., depth of water 5.50 m.); 3°. *the canal through the island of Voorne* (length 9.85 km., depth of water 5.90 m.); 4°. *the canal across the island of Walcheren*, from Flushing to Veere (length 13.27 km., depth 7.45 m.); *the canal across the island of South-Beveland* (length 7.75 km. depth 6.50 m.); 6°. *the canal from Terneuzen to Ghent* (length 33 km., of which 15.2 km. on Dutch territory, depth 6.05 m.); 7°. *the Eems canal*, from Groningen to the Eems (Delfzijl) (length 26·55 km., depth 4.50 m.).

The canals named under 2 and 3 have lost nearly all their importance for maritime navigation since the construction of the North Sea Canal and of the new mouth of the Maas across the Hoek of Holland, but they are still of great value for inland navigation.

The canals across South-Beveland and Walcheren were built in consequence of the establishment of the railway from Roosendaal to Flushing and of the dams of the eastern Schelde and of the Sloe.

The first is used principally for inland navigation, while on the second maritime navigation is confined to the part between Flushing and Middelburg.

The Eems canal has only a secondary importance for maritime navigation as most boats remain at Delfzijl.

It speaks for itself that inland navigation benefits largely by the maritime canals, as shown on attached table A.

b. Canals for inland navigation.

The following are the principal canals constructed especially for inland navigation:

I. In the *provinces of Groningen and of Friesland.*

1. The *Damsterdiep*, from Groningen to Delfzijl 30.9 km.;

2. the *Reitdiep*, from Groningen to the Lauwerzee 31 km.;

3. the *Winschoterdiep* and the *Stadskanaal* (65.2 km.) from Groningen by way of the turf colonies (Hoogezand, Veendam, Wildervank, Nieuw-Stadskanaal) and the turf-pits towards the German frontier, near to which the canal communicates with the Eems;

4. the *canal from Gronigen to Lemmer* (99.9 km.) by way of Bergumerdam, with a branch at *Stavoren* (30.5 km.);

5. the *Lauwerzee Canal* (Nieuwe Zijlen) to *Harlingen* by way of Dokkum and Leeuwarden (62.8 Km.).

The two canals 4 and 5 are connected by various other canals, passing by Dokkum, Leeuwarden and Harlingen. Several canals of small dimensions run into the canal from Groningen to Lemmer; they lead towards the turf-pits in the South-east of the province of Friesland and are in connection with the canals of Drente.

All these canals have an important local traffic besides serving for the outside commerce, which is concentrated, in Harlingen, Groningen and Delfzijl. Boats and steamers carrying goods from Groningen and Friesland to the western provinces pass through canals 4 and 5 and traverse the Zuiderzee.

The dimensions of the above-named canals are very different, especially in Friesland, where they cross several lakes. Although there are parts, which allow of the passage of larger boats, it may be said that in general these canals may be used by boats of a length of about 30 m., of a width of 5 m. and a draft of water of 1.40 to 1.60 m.

The Stadskanaal is only available for boats of a maximum length of 22 m.

The goods transported are principally agricultural produce (potatoes, corn, seed, linseed, straw), industrial products (fecula of potatoes, paper, linseed-oil) turf, cattle, butter, cheese and other articles of consumption, manure and building materials.

II. In the *provinces of Drente and Overijssel.*

1. The *Drentsche hoofdvaart* (principal canal of Drente) from Assen to Meppel (43.84 Km.) in connection on one side with Groningen by the North Willemsvaart and on the other side by

2. the *Meppelerdiep* (11.77 Km.) with the Zwarte Water, a free waterway, leading to the Zuiderzee by the Zwolsche Diep and to Zwolle;

3. the *Willemsvaart* (2.2 Km.) connects the Zwarte Water to the Yssel in Gelderland;

4. the *Oranjekanaal* (48.13 Km.) runs into the Drentsche Hoofdvaart, as does also

5. the *Hoogeveensche vaart* (55.81 Km.), both of these penetrate the extensive turf districts in the South-east part of Drente;

6. the *Dedemsvaart* from the Zwarte Water to the Vecht (39.87 Km.) with a branch to Coevorden, and from there to the Hoogeveensche vaart;

7. the *Overyssel canals* (96.71 Km.) from Zwolle to Almelo (48.06 Km.) with branches to Deventer and to the Vecht and from there to Coevorden.

All these canals serve in the first place for the transport of turf to the towns, to the lime-kilns and to the brick-fields along the course of the rivers, and further, for turf-litter, agricultural produce, manure, building materials and various articles of consumption.

The dimensions of these canals allow of passage to boats of a length of 23 m., a width of 5 m. and a draft of water of 1.25 to 1.40 m. The Overyssel canals are available for boats of a length of 35.4 m. and a width of 5.90 m. The Meppelerdiep and, especially, the Willemsvaart have larger dimensions in order to accomodate the commercial needs of Meppel (cattle, butter) and of Zwolle (cattle, agricultural and industrial products, timber).

Boats in destination for the eastern provinces cross the Zuiderzee.

III. In the *provinces of North Holland, South Holland and Utrecht.*

The North Sea canal with its lateral canals to Spaarndam and to Zaandam, and its junctions to the Zuiderzee; and by way of the Zaan, the Nauerna canal, the Great North Holland canal, the Spaarne and the Canals of Amsterdam to all the navigable ways of Holland is one of most important canal for inland navigation All boats from the provinces of the north-east of the kingdom in destination among other places for Amsterdam, Haarlem, Leyden, The Hague, Rotterdam, Dordrecht, North Brabant, Zeeland and Belgium pass the lock of Schellingwoude.

The Great North Holland Canal, especially the part between Amsterdam and Alkmaar, and the Voorne canal, although deposed from the rank of maritime canals of the first order are both still of great importance to navigation.

Besides these maritime canals we must mention in the first instance:

1. The navigable way called the *Merwede canal* connecting Amsterdam with the Lek and with the Merwede by way of Utrecht, Vreeswijk and Gorinchem (70.9 km.). This canal was opened on the 4th of August 1892 as far as Vreeswijk, and on the 1st of May 1893 as far as Gorinchem. It was newly excavated from Amsterdam to Utrecht; from Utrecht to Gorinchem it follows generally the course of the old canal from Amsterdam to Gorinchem (Keulsche Vaart and Zederik canal), which has been rectified.

The minimum dimensions of this canal are: width at bottom 20 m., depth of water 3.10 m.; the locks have a length of 120 m. and a width of 12 m.

The railways crossing the canal between Utrecht and Amsterdam have been diversed and raised and are laid on fixed bridges.

By this canal Rhine boats of the largest tonnage can reach Amsterdam.

2. The old canal called the *Keulsche Vaart* passes by Utrecht, follows the Vecht as far as Weesp, and flows into Amsterdam by the Amstel. It is joined to the Merwede canal at Nichtevecht, and connected with the Zuiderzee by the Vecht. Its dimensions are very different; boats of a length of 52 m., a width of 7.50 m., and a draft of water of 2.10 m. are admitted. It serves the town of Utrecht and places along the course of the Vecht.

3. The *navigable ways connecting Amsterdam and Rotterdam* are two in number as far as regards the part between Amsterdam and the Gouwe. The boats can follow the Amstel, or the canal along the Haarlemmermeerpolder (the drained lake of Haarlem) to the Oude Rijn (the old Rhine); they then pass by the Gouwe and reach the non-canalised IJssel of Holland at Gouda (51.64 m. from Gouda to Amsterdam by way of the Amstel). These two ways have very various dimensions and allow of the passage of Rhine boats and others of a width of 7.40 to 7.50 m. and a draft of water of 2.10 m. The length of the boats is limited by the lock at Gouda to 46.7 m.

By the *Oude Rijn*, which is a good canal from the Gouwe to Leyden, the boats arrive at Leyden; the Oude Rijn leads also on to Utrecht, but the locks and bridges on this traject are of insufficient dimensions.

4. The province of South-Holland has just lately improved the canal connecting the Oude Rijn at Leyden to the Schie at Delft, so that Rhine boats of a rather large tonnage (such as can reach Delft) can by way of Voorburg reach Leyden, and by a branch The Hague. By these works boats with a draft of water of 2.50 m., a lenght of 51 m. and a width of 7.50 m. will after the completion of the projected port near The Hague be able to navigate between the Maas and this town.

On these canals which communicate with the numerous „grachten" (canals) of the large towns and with the net of small canals and water-courses, which traverse the polders and the villages, transports of every kind are made by boats of every sort and size. They serve equally for commerce towards Germany and Belgium as for transports to commercial ports and the mutual local and interprovincial transport of agricultural and industrial products, cattle, milk, butter and cheese, of building materials, combustibles, manure etc.

IV. In *the provinces of North Brabant and Limburg.*

Here we find

1. The *South Willemsvaart* from Bois-le-duc to Maestricht (122.58 km., of which 77.93 on Dutch territory).

2. The *canal from Maestricht to Liège* (25.35 km., of which 4.94 on Dutch territory) and the *canalised Dieze* (5.79 km.) from Bois-le-duc to the Maas near Crévecoeur.

The dimensions of these canals admit boats of a length of 50 m., of a width of 5 m and a draft of water of 1.90 m. These canals are of great importance for the transport of industrial products from Maestricht, Helmond, Eindhoven (connected by a branch) and Bois-le-duc, of coal etc.

The traffic on the principal canals, *as far as regards inland navigation* is mentioned on the attached table A. In the north-east provinces the greatest movement exists on the Meppelerdiep and on the canal from Groningen to Lemmer. In the south the canal across South-Beveland and the Dieze have the greatest traffic, while in the provinces of Holland and Utrecht the annual traffic on the southern part of the Great North Holland canal, the Merwede canal, the Keulsche vaart, the canal from the Maas via Delft to Leyden and the navigable ways between Gouda and Amsterdam exceeds one million of cubic meters.

It should, however, be remarked that the figures of the tonnage of the canals connecting Amsterdam with the Lek and with Gouda will undergo a change on account of the opening of the Merwede canal. On this canal navigation is entirely free, which fact will lead to a considerahle displacement of traffic.

The Zuiderzee.

The movement of sailing boats and steamers on the Zuiderzee is very intense. About 40 % of the boats pass through the locks at Schellingwoude near Amsterdam. In 1892 the number of boats locked was 94063. The tonnage of these boats at its maximum is 190 cubic meters; sailing boats have an average tonnage of 60, and steamers of 110 cubic meters.

The transport of passengers on the rivers, on the canals and the Zuiderzee.

The transport of passengers on the navigable ways of the Netherlands deserves special mention. It is carried on by steamers and not only on the Rhine and its branches, on the Schelde and on the Zuiderzee, but, also, on the canals. Although the ancient „trekschuiten" (towed passenger boats) have disappeared nearly everywhere, the passenger traffic on canals has not diminished; but, the old medium of transport is replaced by a better one, viz., by steamboats. These steamboats have great advantages. The transport is effected cheaply, the journey is easy and agreeable, the boats pass through the villages, follow the course of the canal in all its extent and penetrate into the towns, and they travel at a good speed. There are districts in Friesland and especially in Holland, where the steamboat is the only means of transport, as the railway is too far away and the dikes along the canals are too narrow for transport by land (1).

In the same way for many places along the river sides the steamboat is the most preferred means of transport; for the inhabitants of the islands of South Holland, of Zeeland, of Flemisch Zeeland etc. it is indispensable.

Statistics of the number of passengers carried are wanting, but the number is considerable (2).

There are at the present day about 130 companies, or contractors, who have established regular services of steamboats for these transports on the rivers, on the canals and on the Zuiderzee. It is understood that these boats also carry cargo. The speeds are different; on canals where the speed is limited by police regulations the commercial speed is generally 6 to 10 km. per hour, but it is, also, often from 10 to about 15 km.

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(1) The condition of the towns and villages on the sides of navigable canals and the considerable expense incurred by the construction of roads on account of the configuration of the land and the want of solidity in the soil explain the developement of the «trekschuiten» in Holland and make clear the predeliction for this method of transport at a period when time was not of great value. The first railways encountered serious opposition; many people believed them to be useless, or at least superfluous. The report to William I, by the official commission for the study of the question of the establishment of railways in Holland is very curious. The commission was of opinion that the construction of a railway from Amsterdam to Arnhem would be desirable, especially in view of the establishment of a railway from Antwerp to Cologne by the Belgians. This railway could be extended later on to Lobith on the Rhine and perhaps to Cologne.

A railway for Rotterdam did not appear in any way urgent. The transport of goods and passengers from Rotterdam to Cologne was regularly effected by steamboats, which made the journey, in five days, including delays. And commerce did not demand such speed. Even the company for navigation to Cologne refused to pay 18 centimes per 50 kgr. (3.60 francs per ton) for towage from Rotterdam to Lobith and preferred to make the journey from Rotterdam to Cologne in 16 days instead of in 8 or 5.

The vice-president of the Chamber of Commerce of Rotterdam not agreeing entirely with the conclusions of the commission presented a special note to the King. Not only did he consider a railway for Rotterdam useless, but his opinion was that all requirements were sufficiently met by steamboats following the Lek, with a corresponding service of boats towed at a high speed from Vreeswyk to Amsterdam. The Netherlands Steamboat Company at Rotterdam was disposed to undertake a service of this kind. If the transhipment of goods and passengers at Vreeswyk required too long a time, the steamboat could take the »trekschuit" in tow and the transhipment could be effected on the way.

The vice-president hoped that the commerce of Amsterdam would make a trial of this plan.

Times are much changed. We must not, however, lose sight of the fact, that in 1835, (the report is dated 1836) the total traffic by the Rhine from Rotterdam to the German towns from Wesel up to Mannheim, only amounted to 45426 tons, of which 21038 tons were for Cologne. In 1893 the total movement of the Rhine to Lobith was: goods entering 2929056 tons of 1000 kgr., of which 537979 for Rotterdam; goods leaving 3804399 tons, of which 2752070 came from Rotterdam.

(2) The service from Enkhuizen to Stavoren carries more than 80000 passengers per year.

The large boats (with paddles-wheels) of the steamship company from Cologne to Dusseldorf do the traject from Arnhem to Rotterdam, via the Lek (122 km.) in 7 and in the contrary direction in 8 hours, while the boats of the Dutch Steamnavigationcompany between Nymwegen and Rotterdam via the Waal (111^5 km.) take 6 and in the contrary direction 8 hours, which gives the commercial speeds of 14 to 15 km. per hour for the ascent and about 18 km. for the descent.

The steamboats of the Dutch company have the following dimensions: length 71 to 73.4 m.; width 13 to 14.3 m.; draft of water when loaded 1.02 to 1.40 m. The engines have 100 to 120 horse-power. The largest boats can carry 1500 passengers. The steamboats running between Rotterdam and Gorinchem are of 80 to 100 horse-power.

They have a length of 45 to 60 m. and carry 700 to 1000 passengers. The smaller river boats can generally carry 200 to 300 often 500 to 800 passengers. The length varies from 20 to 50 m. and the draft of water from 1.10 to 2.25 m.

The dimensions of boats navigating on the canals are less, the length varying from 15 to 35 m.; it is often 20 to 25 m.; the draft of water varies from 1.00 to 1.50 and reaches sometimes to 1.80 m. These boats can carry 80 to 100, and sometimes 150 to 200 passengers. Generally, their power is 12 to 20 horse, although there are some, which are only 6 to 8 horse-power.

II. MEANS OF TRACTION AND PROPULSION IN USE ON THE RIVERS AND ON THE CANALS IN THE NETHERLANDS.

On the „grachten" (canals) of the towns boats are often propelled by means of a hook or towed by men. The hook is also used for the purpose of moving small boats on small canals and on water-courses, which have no tow-paths and in the „polders". Towing, often by men and unfortimately, also, often by women is practised on a number of canals when the boats are not able to use sails, or when the canals do not allow of navigation by sailing. In these cases boats of a certain tonnage, or those which demand a greater speed are towed by horses. Most of the canals are provided with tow-paths, at least on one side of the canal.

Navigation by sail is much practised and this is easily explained. The small boats, which navigate the rivers and the arms of the sea in the south-west part of the Kingdom, or which cross the Zuiderzee, are necessarily arranged in such a manner that they provide their own means of transport, tugging being too dear or impracticable. Also, many canals, which cross small lakes, or follow waterways around drained parts are sufficiently wide to allow in this flat country, where there is nearly always wind, of navigation by sail.

In addition to sailing boats there is an increasing number of steamboats.

Steamnavigation on the Rhine dates from 1816; since then, this navigation has expanded itself on all the rivers and all canals of any importance.

We have already mentioned passenger boats; the minority of these are paddle boats, for example, the boats from Rotterdam to Mannheim to Gorinchem, to Nymwegen, to Bois-le-duc, to Antwerp by the rivers, and from Amsterdam to Zwolle and to Harlingen, via the Zuiderzee etc.; most of the boats are screw-boats; including cargo and tug-boats. With rare exceptions only screw-boats are found on canals.

The number of steamboats of all kinds, at present in service on the rivers, the canals and the Zuiderzee may be estimated at 1250 (1).

In 1891 there were in Friesland 80 different services. In 1892, 185 services were in existence in South Holland. There were 185 boats for the transport of passengers and cargo in this province and 230 tug-boats. Companies and contractors owning real fleets of tugs for inland navigation are to be found at Amsterdam, Rotterdam, Sliedrecht, Alblasserdam; as also at Dordrecht, Gorinchem, Gouda, Oudshoorn and Utrecht; others at Arnhem, Nymwegen and a few at Groningen, Harlingen etc.

Among the boats which navigate by means of tugs, should be mentioned in the first instance the Rhine boats of all sizes, then the small boats, which are not rigged out for sailing and the tjalks and other boats laden with turf, hay etc. tugged in trains.

The power of the tugs is very varied. With the exception of those, which serve for sea-going vessels (the horsepower, of which amounts to 100, to 165 and even to 200) the tug-boats for inland navigation are 10 to 90 horsepower, very often of 10 to 20 on ordinary canals, and of 20 to 50 horsepower on rivers and large canals.

Passenger, cargo and tug-boats are worked by steam. Lately, however, small petroleum engines have been introduced on some small boats, which depart at regular hours. These engines, which are of several horsepower work the axle of the screw by the aid of belts. Constructed in the works of Mr. VAN RENNES at Utrecht, they have given very satisfactory results.

Navigation on rivers and canals is controlled by laws established to

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(1) Official detailed statistics show that on the 1st of January 1883 there were:

18	steamboats of 1202 horsepower for the river service towards Germany,
18	steamboats of 684 horsepower for the river and canal service towards Belgium.
518	steamboats of a total power of 10911 horse (averaging 21 horsepower) for inland transport on rivers and canals.
and 317	tug-boats of 9221 horsepower (average 29 horsepower).
Total 871	steamboats.

Since that year no such detailed statistics have been published.

prevent collisions on the public waterways of the Kingdom, which are open to navigation, and by laws concerning the transport of gunpowder and other inflammable or explosive materials, and the maritime works of the State; as well as by the stipulations and regulations consequent on these laws.

Navigation is generally regulated: 1°. by general police rules on the rivers, canals, ports, locks etc. administered by the State, fixed by Royal decree of August the 13th 1891, and by various special police rules referring to these rivers, canals etc.; 2°. by regulations of the provincial police and others on the canals administered by the provinces, the communes etc.

The act respecting navigation on the Rhine, concluded between the bordering states, stipulates that navigation on the Rhine and its affluents shall be entirely free to boats of all nations, from Basel to the sea, with some exceptions prescribed in the same act or by police regulations.

The police regulations, general and special, are very liberal with regard to towage, which is free, as also, with regard to steam navigation on rivers and canals. Steam navigation is allowed on all canals of any importance, with the exception of the Oranje canal, where it is forbidden and on a few canals in Overijssel, where it is only allowed by special authority. On some canals in Drente and in Overijssel and in the turf districts steam navigation is not exercised on account of the insufficient dimensions of the canals and of the large number of locks.

Table A shows the maximum dimensions of boats admitted on the principal canals, the maximum speed allowed to single boats and to tugs, and the maximum number of boats allowed to be tugged in train. The speed allowed depends on the draft of water of the boat. Near to bridges, locks etc. and when passing boats going in a contrary direction, or boats heavily laden, boats loading or discharging etc. speed must be reduced to 75 m. per minute.

For steamboats with a draft of water not exceeding 1.25 m. the minimum speed is — with some exceptions — 140 to 250 m. per minute or 8.4 to 15 km. per hour. The speed for tugged trains is sometimes limited to 80—100, on some maritime canals to 150 m. per minute; the number of boats tugged in trains varies from 4 to 8 for small canals and from 8 to 18 for large canals.

On the small canals of Friesland, where the depth of water is about 1.50 m. small boats with a length of 20 m., a width of 3.40 m. (1) may travel during the day at a speed of 133 m. per minute and at night of 100 m.

On the canal from the port of Edam on the Zuiderzee to the Great North-Holland canal at Schouw (via Monnikendam), the maximum speed of steamboats is regulated in a special way. This canal is of small dimensions (1), and when steamboats travelled at an unlimited speed the damage suffered by the banks and slopes was alarming. It was decided to fix maximum speeds to be allowed, but special experiments showed, that the rate of progress of the boat no longer increased beyond a certain number of revolutions of the screw; and that, then, the extra work of the engine only served to increase the wash of the water and the destruction of the banks. With a limited speed of rotation of the screw nearly the same rate of progress could be attained without damaging the bermes and the banks (2). Since then, the maximum number of screw revolutions has been fixed at 120 to 140 per minute according to the dimensions of the canal. This regulation allows of easy control. It appears to me that these experiments are worthy of the attention of all engineers interested in the question of traction and propulsion on canals.

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(1) These boats run the service Gorredijk, Drachten, Heerenveen.

They prove that on every navigable way there is a certain limit of speed depending on the proportion between the dimensions of the canal and those of the boat. Beyond this speed the increase of engine power as well as powerful protection of bermes and banks may be considered as useless expense.

In order to accelerate the speed of boats, we must commence by diminishing the resistance of the water, and facilitate the efflux of the water at the side and under the boat; that is to say, change the form and the dimensions of the boat or enlarge the canal.

III. THE NEW SYSTEMS OF TRACTION PROPOSED OR ATTEMPTED.

Several systems of traction to replace towage by manual labour, by horses and by tug-boats have been proposed, tried or put in regular service.

These systems of towage may be called generally mechanical systems.

The systems are applicable in the first instance to boats, which have no other means of propulsion (as sails, wheels, screws etc.), but the question has been raised, whether these sould not be preferred on canals to other systems of propulsion from the point of view of economy and regularity.

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(1) The depth at bottom is 8.4 to 9.2 m., the width at the floating level 17.2 m. the depth of water 2.10 to 2.20 m. The maximum dimensions of the tjalks are: width 4.50, draft of water 1.70 to 1.80 m.; maximum dimensions of steamboats: length 31 m., draft of water 1.70 m.

(2) See the communication of Mr. Scholtens, Chief engineer of the provincial Waterstaat in the province of North Holland at the meeting of the Royal Institute of Engineers on the 14th of February 1893. (Tijdschrift van het Koninklijk Instituut van Ingenieurs 1892/93. Notulen der vergadering. Derde allevering). Messrs Deking Dura and van der Vegt have made the same observation on the canals in Overijssel and in South Holland (See the account of the above mentioned meeting).

The varions systems may be divided in two groups, comprising, 1°. systems of *tugging* or *towing by an immersed chain or cable;* 2°. systems of towing by *cables worked from the banks of the canal.*

a. Towage.

Towage has been in practice for a long time on several rivers, among others on the canalised Seine, the Elbe, the Rhine between Bonn and Bingen, the Neckar, the Danube, the Belgian canalised Maas, and it may be safely asserted that this system is of great importance, where it is a question of considerable traffic on rivers with strong inclines. In such cases and, especially, if the depth of water is weak the tow-boats surpasses all its rivals in navigating on the ascent. It is not at all the same thing on rivers with a small incline especially, if the width and the depth of water are sufficient. The towage established on the lower Rhine between Rotterdam and Ruhrort had no success; and the service was suspended in 1878 after a short existence.

We may say that towage by cable or chain offers no advantage of any importance for navigation on rivers of a free current in the Netherlands. Strictly speaking we might except the Maas from Venloo to Maestricht, which is scarcely navigable on account of its strong inclines and insufficient depth of water; but the canal from Maestricht to Bois-le-Duc takes the place of the river.

Towage has not been much employed on canals, because, as a rule, traction on canals does not necessitate much power.

Again, locks are often an obstacle to the formation of suitable trains. The system has the advantage, that it spares the banks; on the other hand the speed is limited.

Above all, the meeting of two trains gives rise to difficulties and considerable loss of time, because each tow-boat has to exchange his train for the other. Therefore, the canal should be divided in sections, on which the tow-boats make a regular service in turns. This requires a large amount of plant and great regularity. Or the tow-boat might descend and ascend the canal in its entire length, which would lessen exceedingly the number of trains per day.

The system of drawing on a chain, which is rolled a number of times on drums, or on a cable, which is seized by the claws of a Fowler pulley gives rise to extraordinary tension, which causes rupture of chain or cable.

To obviate these defects of the system, which are in part, also felt on rivers and on canalised rivers Mr. Bellingrath has invented and applied on the tow-boats on the Elbe, pulleys which exercise only a normal tension on the chain. Mess^rs^. Molinos and de Bovet have sought for and found a new system, which allows of the throwing of the chain into the water without difficulty at any point of the journey.

This system is composed of a pulley of which the points constitute the two poles of an electro-magnet, by which the chain is kept in its place. They propose to replace the present tow-boats by others furnished with an apparatus which should only be used on the ascent. Their system could also be applied on canals.

Messrs. Molinos and de Bovet propose to place on the boats a small magnetic pulley and a dynamo capable of giving a three horse power, which would be sufficient to render to the boat speed of 3 Km. per hour. The machine, of a total weight of 1500 Kg. would be put on board at the entrance of the canal and delivered up on leaving. Two cables connected at certain distances above or below the canal would form the electric conductor, furnishing the current to boats ascending and descending by means of runners and flexible wires in the manner employed on electric tramways. The wires would be in connection at one of their ends with the runner and at the other with the dynamo and supported by a pulley fixed to the mast and so maintained above the tow-path.

Works for the production of electricity would be distributed along the canal.

The immerged chain would weigh 4 Kg. per meter.

In a large canal there would be two chains.

This arrangement is without doubt practicable and even attractive; it appears, however, to be not without difficulties. In the first place the system has the same fault as that of Mr. Bougnie, who also, made the proposal of placing transposable traction apparatus on each boat (pression pulley and locomobile). It is true that the weight of the apparatus proposed by Mess. Mollinos and de Bovet is not excessive, at least for a speed of 3 km., but the placing on board of the boat and the establislement of the chain, as well as the discharge would take up much time and necessitate the use of cranes. This inconvenience would especialy be felt on short canals. It appears to me, also, that it is not an easy matter to throw the chain and to take it up again at the meeting of two boats, and these meetings would be rather frequent, as the boats would travel singly. For the placing of two chains the bottom of the canal would have to be very wide; otherwise, the chains would be likely to mix one with the other. And even on very wide canals this danger would still exist on curves; while we must not lose sight of the fact, that boats, and in the first instance those with a great draft of water always seek to follow the axis of the canal, especially at night, in order to avoid damage, and they are obliged to keep at a distance from the banks to avoid encountering boats and rafts moored there. For higher speeds the system becomes impracticable and complicated if the tonnage of the boats varies much, and it becomes necessary to have a supply of apparata of different sizes and powers.

The same defects are found in the system of Mr. Büsser (at Oderberg) who also proposed to provide each boat with a pulley and a dynamo, and to work the dynamo by an electric current conducted by cables along the canal.

It may be asked if it would not be better to establish the apparatus (pulleys and dynamo) on small tug-boats continually in service on the canal. This would necessitate a staff of attendants, but on the other hand there would be no need for a staff for loading and unloading the apparatus and much time would be gained.

The question of motive power could then be separated from the question of traction, which would be a great advantage. By placing the transposable apparatus on board of the boat we are necessarily obliged to establish an electric current along the canal, as the loading and discharging of locomobiles would be impracticable. By placing them on board of small tug-boats any motive power and any kind of motor could be used, electricity, ordinary steam engines, steam engines of the SERPOLLET system, petroleum engines, accumulators etc. The SERPOLLET engines, petroleum engines and accumulators are very convenient and economical and are especially worthy of attention.

In this case the steam of steamboats could be employed to set the pulley and the dynamo in movement, which would permit of the passage of these boats on canals on which the use of the screw could not be allowed. On leaving the canal the steamboats would continue their journey in the usual way.

Towage is applied with much success on the St. Quentin canal (ordinary towage) and lately at Pouilly on the Burgundy canal according to the project of Mr. GALLIOT (electric towage: tow-boat with pression wheel and dynamo receiving the electric current by conducting cables along the canal; the current is provided by the turbines).

But in this case the boats have to be passed through short tunnels (of a few kilometers), where the canal has only a single way and boats navigating in trains pass alternately in one direction or the other.

Towage is also applied on the canal from Brussels to Willebroeck; trains travel there at a rate of 5.1 km. per hour, and in a satisfactory manner. But, the service is established by the town of Brussels, which owns the canal, and towage (in trains) is obligatory.

It appears to me that we may conclude as follows: A satisfactory solution to the problem of towage on canals seems to be not yet found. Towage by magnetic pulley shows great progress as regards mechanical traction on rivers and canalised rivers. With respect to traction on canals, the employment of the magnetic pulley invented by Mr DE BOVET may offer the same important advantages, but the most practical application of it has not yet been discovered and further studies and experiments are required.

b. Traction by machines or apparata, placed along the canal.

The remarkable experiments in traction by machines or apparata placed along the canal, which have been made in France and in Prussia include cable towage and towage by locomotive. These experiments are too well known to be given here in detail. (1)

Cable towage has been tried in practice by Messrs Rigoni, Oriolle and Levy, but it is only the system of Mr Maurice Levy, which has been the object of very serious experiments on the part of the French and the Prussian governments. The system has been in use a certain time on the St. Maur canal and on the St. Maurice canal near Charenton, where all possible technical difficulties are united. The system is to be definitely established on the dividing reach of the canal from the Aisne to the Marne (in the tunnel) and studied, also on a section of the St. Quentin canal.

The experiments made in France and in Prussia have shown that the system is practicable and that it will probably render very satisfactory results from an economical point of view.

The extremely simple and ingenious manner, in which the boats are attached to the endless cable allows each boat to commence and to terminate its journey at any place and at any moment. The question of passing the attachment rope by the pulleys has, also, found a perfect solution.

Nevertheless, the experiments have shown one great difficulty, viz., the rotation of the endless cable. We must believe, however, that this will be obviated. (2)

However, the question, whether this ingenious system can be applied with success to the working of canals of a certain length and, on which there is a very variable traffic of boats of different tonnage is still open.

In such a case the canal would have to be divided in several rather small sections, each having its own endless cable. But, nevertheless, the number or the total tonnage of the boats moored at one time to the endless cable might become too great; besides, the attachment of boats exceeding a certain tonnage might give rise to shocks and cause ruptures.

The endless cable must be in continual movement during all the day and during a part of the night, even if there are no boats. This movement together with the side pull of the boats must cause a very great wear of the cable, as well as of the pulleys, especially in curves. The changing of the cable must take up considerable time. In order to avoid interruption to the navigation the change will be effected on Sundays or in the winter, but in case of breakage of the cable, navigation will be necessarily interrupted and the effect of the accident will be felt on every part of the canal. These breakages may become dangerous, especially in the middle of villages situated along the canal.

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(1) In 1891 I had the pleasure of giving a full account of these experiments in «De Ingenieur» no. 4 of 24th of January.

(2) Mr Büsser (of Oderberg) has proposed the employment of a flat cable instead of a round cable and to work it by means of electric motors.

The speed is restricted and does not exceed 0.7 m. per second ($2^1/_2$ km. per hour), but there are hopes that it may be brought up to 1 m. per second or $3^1/_2$ km. per hour, which is certainly the extreme limit in view of the attachment of boats of a large tonnage. The speed is, of course, absolutely the same for all the boats.

Traction by locomotive, first tried in France, under very unfavourable conditions, has been again tried in Prussia· From a technical point of view the results were satisfactory, but from an economical point of view not at all so. Still, it seems to me, that in certain cases this system may offer real advantages. The rate of speed may be brought up to 2 m. per second (7.2 km. per hour) if not more, and the wear is but small. The expenses of first establishment are great, but do not much exceed those of cable towage, which are estimated at 18000 to 25000 francs the kilometre, at least when the road at the side of the canal admits of the laying down of rails. This road must be sufficiently wide and the canal must not have curves of too small a radius, or have many locks.

The employment of ordinary locomotives, which are not very economical machines would generally render the working expenses too high. It, also, appears to me that engines of a rather low power, worked by electricity might afford the best results. The arrangement would then resemble that of an electric tramway, if necessary with cogs, which instead of drawing carriages would draw a boat or a number of boats.

IV. THE QUESTION OF PROPULSION AND TRACTION ON THE CANALS IN HOLLAND.

We need not speak of the rivers and of the Zuiderzee, on which mechanical towage is excluded, and on which the present systems of propulsion (sailing-boats, steam-boats for passengers and for cargo, with screws or with paddles, tug-boats) have taken sufficiently definite forms, which, although they certainly allow of much improvement comply very well, on the whole, with the requirements of the traffic. The same may be said of the maritime canals; there remain, therefore only the canals for inland navigation, the net of which is divided by the Zuiderzee and the rivers, in such manner that the length of the canals is limited. On leaving canals boats are obliged to have recourse to tugs, to sails or to their own steam engines.

The new systems of mechanical traction of which we have spoken above are confined to the canal on which they are established, which constitutes a disadvantage in comparison with tugs and cargo-boats. They require a regular service, which always becomes expensive, for the service must be so organised as to comply — as far as possible — with the maximum traffic, while, as a general rule, the traffic is not at all regular. Consequently, the prices of transport or the prices of traction per kilometre ton do not descend to a sufficiently low point unless the total transports are considerable. It has been calculated, that the annual minimum traffic necessary to render cables towage remunerative is about one million tons.

Table A shows that this tonnage is nearly attained or exceeded on the following canals: 1°. from Groningen to Lemmer; 2°. the Meppelerdiep; 3°. the Great North Holland canal; 4°. the Merwede canal; 5°. the Keulsche Vaart; 6°. the canal from Gouda to Amsterdam via the Gouwe and the canal along the drained Lake of Haarlem; 7°. the Amstel; 8°. the canal from Delfshaven to Leyden; 9°. the canalised Dieze; 10°. the canal from Maestricht to Liege; 11°. the canal across South-Beveland.

However, the figures of the annual tonnage only refer to a certain part of each canal; also, they do not represent the weight of goods carried, but give only the measure of capacity of the boats (1).

Of these canals nos. 2, 9 and 11 are too short and their condition is of too special a nature for them to be suitable for the establishment of mechanical traction.

On the canals nos. 1 and 3 to 8 there is a very intense local navigation of small boats, which travel only small distances. The number of locks on these canals being very few, it is not quite clear in what way a regular service for this local navigation could be arranged. Cable towage would allow free movement to these small boats, but, as this movement is often on one part of the canal between two locks, it would be necessary to hire out the attachment cords by space of time. It is to be feared that such an arrangement would not be successful, especially, on account of the opportunity it opens for fraud and of the difficulty of control. Neither is the system of Messrs Molinos and de Bovet suited to this local navigation. Only traction by locomotive, by special tow boat or tug is applicable to boats, which have to travel a certain small distance.

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(1) If we calculate the average tonnage of the boats, we obtain the following figures: 50, 60, 45°, 67 to 81. 42, 80, 62, 16 to 23, 80 124 and 106 cubic meters. These average figures have no real value. but they show clearly 1°. that the dimensions of the boats are very varied, and 2°. that on the canals (for example nos. 3, 4, 5, 6: 7 and 8) which are navigated by boats of a large tonnage, the number of small boats is so great that the average tonnage remains small.

For success a considerable and continuous traffic on the whole of the length is needed and this is only to be found on the canals connecting Amsterdam with Gouda and with the Lek at Vreeswijk (Merwede canal).

These two canals are in the first instance worthy of study and after them the canal from Groningen to Lemmer and that from Liege to Maestricht, and perhaps also the canal from Maestricht to Bois-le-duc. On this last the total tonnage does not reach the desired limit, but the transitory or direct traffic is of sufficient importance. Traction by locomotive and cable towage are excluded on the canals from Groningen to Lemmer and from Amsterdam to Gouda on account of the lakes, of the want of solidity in the land and of other local difficulties. On the Merwede canal from a technical and local point of view the various systems are practicable.

Nevertheless, a great difficulty remains, that is, the financial question. The cost of first establishment and the working expenses are very large and the competition of other means of traction very active.

The French canals are in a much more favourable situation, as regards the application of new systems of traction. They are of great length and their locks are of nearly uniform dimensions. There is a very considerable traffic of goods transported from one river-basin to another, a traffic which traverses the whole or, at least, a great part of the canal, while the large number of locks is a serious obstacle to steam navigation Nevertheless, in France, as elsewhere, the difficulty has been felt in the establishment of mechanical traction of ensuring the quantity of transports necessary to reduce the price of traction to such a point, that it can compete with the systems of traction in use.

In the Netherlands this struggle is especially difficult, because steam navigation is nearly everywhere allowed and possesses incontestable advantages. The tugs travel at a rather high speed and take boats to almost any place. Mechanical traction can only serve on a part of the way. Certainly, the latter system may allow of more regularity and of transport at fixed prices, but these advantages are counterbalanced in part by the loss of time incurred in the formatiou of trains, the delay in waiting for the train travelling in the opposite direction or the restricted rate of speed, while regularity is in the highest degree uncertain by the moveable railway bridges (1).

In order to obviate the financial difficulties, which oppose the establishment of new systems of mechanical traction, it has been proposed to create monopolies of traction on canals.

The idea has been already put in practice by the town of Brussels. It appears to me, however, that to this serious objections may be raised.

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(1) The section of the Merwede canal from the Lek to Amsterdam is the only canal, which is crossed by railways on elevated fixed bridges.

It is evident, that in creating this monopoly an exception must be made with regard to boats possessing their own means of propulsion.

The question is thus confined to boats tugged or towed, but it may be asked by what right could towage by manual labour or by horses be forbidden, and for what motive tugging could be prohibited, if the dimensions of the canal and local circumstances admit of it. It must not be forgotten that the price of traction constitutes only a part of the expense of transport and that these expenses themselves do not form the only factor to be taken into consideration. Frequently economy of traction must be subordinate to the working and commercial requirements.

The example of railways has been quoted and a proposal has been made to establish analogous services on canals. But there is an enormous difference between railways and canals, which admits of no comparison as regards the working. Canals are ways of communication open to all the world; on railways it is absolutely impossible to allow any such liberty of movement.

In spite of incontestable prejudices, an almost absolute monopoly has had to be created, but this monopoly, a necessity for the public security, gives at least some real advantages, such as that of transport at a high rate of speed and at very moderate prices.

Further, railways take charge of the transport of goods to their destination, while on the canal the Company (or the State) enjoying the monopoly of traction certainly does not attend to the ulterior transport.

It is, thus, to be foreseen that a monopoly of traction on a canal would not benefit commerce; on the contrary, the speed of transports would often be reduced, and, above all, small inland and local navigation, requiring, as it does the greatest liberty and simplicity would suffer.

With regard to the Netherlands, I am pleased to believe that, with a few exceptions in special cases every system of traction, which does not admit of the employment of other means of traction at the same time and which restrains liberty of navigation is inadmissible, as is, likewise any monopoly.

V. CONCLUSIONS.

Inland navigation demands greater regularity, a higher rate of speed and a diminution of expense. A good working only being possible on canals which are properly established, the State and the proprietors of canals should endeavour to abolish all obstacles, which stand in the way of these legitimate requirements. In this respect there is much to be done.

Locking generally takes up far too much time; and the moveable bridges on railways are the cause of considerable delays. Any increase of the rate of speed will be useless, all improvement in the regularity of the service or in traction will be without effect unless these serious difficulties are remedied.

More uniformity should exist on canals, in the sense that the navigation of a canal or of a net of canals should no longer be ruled by the dimensions of a single lock, a single bridge or of a local depth, and boats of an average tonnage should be able to navigate all the principal ways.

The more important canals, which connect the sea-ports and the large commercial towns with the rivers deserve special attention. In the first place the canals from Amsterdam to the Rhine and from Amsterdam to Rotterdam should comply with all the requirements of a large fluvial navigation. It should be possible to lock entire trains, and the locks should be furnished with suitable apparatus for accelerating the process of locking.

The loss of time and the delays in the ports should be reduced; the appliances for loading and unloading require considerable extension.

Every possible facility should be accorded to steamnavigation; and with this object various canals should be rectified, widened and deepened. The enlargement of cross section, by diminishing enormously the resistance of the boats appears preferable to any other method for the protection of the bermes. In cases where the width of the canal cannot be increased without incurring too much expense, the lowering of the bed may afford an efficacious improvement. The great effect of depth is clearly demonstrated by the experimental researches of Mr. CAMÉRÉ.

Locks should be so constructed as to allow of several boats being locked at the same time. On canals of limited dimensions the employment of two small locks side by side seems preferable to the employment of one larger lock. Small locks at the side of larger locks would be also very useful on large canals.

By these means, as well as by the lowering or the abolition of tolls the working expenses would be reduced to the utmost degree.

In this manner endeavours should be made to gradually create navigable ways allowing on all of their parts an ordinary average speed of at least 10 to 12 km. per hour to steamboats travelling singly; and this seems possible without the outlay of extravagant sums.

On the other hand navigation should tend to a more complete utilisation of plant and more unity in working. This object might be obtained by association, which at the same time might lead to more stability in the tariffs for tugging. A service in turns on the rivers and on the principal canals by cargo and tug-boats would probably give satisfactory results.

With regard to the question of the most economical organisation of traction and propulsion on canals, properly speaking, it is not yet solved in a definite manner. Practically at least, it does not seem capable of a general solution. Each case demands special study, taking into account local circumstances, the dimensions of the canal and of the boats, the division of transports etc.

Besides, the question of propulsion and traction cannot be treated separately, but must be connected with that of the working of the canal or canals on all their length with regard to the requirements of commerce.

The creation of a monopoly of traction on a canal appears not admissible except in special cases.

The study of the entire net of navigable ways in the Netherlands leads us to the conviction that for most of these canals the systems of free propulsion of boats and of traction by tug-boats should be placed in the first rank. These systems allow a high rate of speed; they are suited for general use; they are capable of taking boats to any place on a navigable way and into the centre of towns, while allowing the greatest liberty to the entire navigation. Above all the navigation of cargo boats, tugging in case of need one or two boats appears to merit special attention. The free movement of each boat permits of its travelling without danger at a higher rate of speed than can be allowed to trains, which, together with the absolute independance enjoyed constitutes a great advantage.

The most useful manner of employing small motors worked by steam (SERPOLLET among others) by petroleum (VAN RENNES) and electricity (accumulators etc.) capable of being used on small boats must await a more special study.

On some canals which have a regular and direct traffic, in the first place on the canal from Amsterdam to the Lek at Vreeswijk, cable towage, traction by locomotive and towage by a tow-boat furnished with a magnetic pulley are worthy of full examination.

Finally, it is of the highest importance to continue on the canals of the Netherlands with boats of various forms the experimental researches of Mr. CAMÉRÉ and of Mr. DE MAS, as well as those concerning the most suitable rate of speed for screw-boats.

In concluding, I express my hope that at the VIIth International Congress on Inland Navigation the Dutch engineers will be able to produce results of new trials of traction and new experimental researches worthy of a place by the side of the remarkable researches and experiments made in France and in Germany, and worthy of the „country of canals."

The Hague, July 1894.

Translated by G. I. ROWLAND.

NAME OF CANAL.	Minimum dimensions of canal.			Maximum dimensions of boats or steamboats (s).			
	Width at floating line. M.	Width at bottom. M.	Depth. M.	Length. M.	Width. M.	Draft of water. M.	up to 1
Canals in the provinces of Groningen and Friesland.							
1 Eems canal (from Groningen to the Eems near Delfzijl)	31 to 40	12 to22	4.50	—	10.50	4.25	. . . .
2. Damsterdiep (from Groningen to Delfzijl)	10	6	1.70	—	5	—	140 to
3. Reitdiep (from Groningen to the Lauwerzee).	20 to100	10	2.50	—	—	—	. . . .
4. Winschoterdiep (Groningen—Zuidbroek)	18 to 20	7 to 12	2.00	—	5	—	150
and (Zuidbroek—Wildervank).	11 to 14	7 to 9	1.80	—			
Stadskanaal (Wildervank—Ter Apel)	11.50	7	1.50	—			
5. Canal from Groningen to Lemmer via Bergumerdam and branch to Stavoren	—	14 to30	2.00	30 (s)	5 (s)	1.60	. . . .
6. Canal from the Nieuwe Zijlen (Lauwerzee) to Harlingen via Dokkum and Leeuwarden	—	6 to 16	2.10	30 (s)	5 (s)	1.60	. . . .
Canals in the provinces of Drenthe, Overyssel and Gelderland							
7. Drentsche Hoofdvaart (Canal from Assen to Meppel)	14.50	8	1.80	—	5	1.25	125 to
8. Meppelerdiep (Meppel—Zwartsluis)	21 to 32	13 to24	1.90	60	7.80	1.80	200
9. Dedemsvaart (from Hasselt to the Vecht).	13	6.50	1.60	23	5	1.30	—
10. Overijsselsch canal (from Zwolle to Almelo) with branches	14.30	7.50	1.70	35.37	5.90	1.41	110 to
11. Willemsvaart (from Zwolle to the Yssel)	22 to 28	14 to18	3.15	94.75	11.80	3.00	150
12. Apeldoornsch canal (Dieren—Hattem)	10.50	5	1.62	21.50	4.15	1.38	75
Canals in the provinces of Holland (Nord and South) and of Utrecht.							
13. Noordzeekanaal (North Sea canal) Amsterdam—IJmuiden	68	20	7.70	115	17.75	7.30	250
14. Great North Holland canal (Amsterdam—Nieuwediep)	38	10	5.50	64	15	4.80	250
15. * Merwede canal (from Amsterdam to the Merwede)	32	20	3.10	80	10.50	2.60	200
16. Keulsche vaart (canal from Amsterdam to Lek via the Vecht)	13 to115	13	2.25	52	7.50	2.10	180
17. Oude Rijn (from Leyden to Gouda)	—	—	—	—	—	—	. . . .
18. Canals from Amsterdam to Rotterdam:							
1°. from the Yssel (Gouda) to the Oude Rijn via the Gouwe	—	—	—	46.7	7.50	2.10	. . . .
2°. from the Oude Rijn to Amsterdam via the Amstel	21 to120	—	2.25	—	7.50	2.10	. . . .
3°. from the Oude Rijn to Amsterdam via the canal along the Haarlemmermeerpolder	10 to300	—	2.25 to4.00	—	7.40	2.10	. . . .
19. Canal from Delfshaven to Leyden:							
1°. Delfshaven—Haagvliet	27	16	2.80	51	7.50	2.50	—
2°. Haagvliet—Leyden	22	12	2.50	40	5.35	2.20	—
20. Canalised Yssel of Holland (Canal from Gouda to the Lek via Oudewater)	11.70	6	2	26	5.30	1.50	180 to15
21. Voorne canal	37	10	5.90	110	13.70	6.00	250

in M. per minute ling singly.				Maximum speed for tugs in M. per minute.	Maximum number of boats in a tugged train.	Annual movement of inland navigation boats 1892.		
in M.	2.01 to 2.50	2.51 to 3.00	more than 3.00			Number of boats.	Total tonnage in cub. metres.	PLACE.
100	. . .	. . .	. . .	—	—	1413	63808	Groningen.
	—	—	—	—	—	5186	156919	Swingbridge at Winneweer.
. . .	. . .	. . .	. . .	—	—	5239	276428	Lock at Wetsinge.
	—	—	—	—	—	13600	685000	Lock at Veendam.
	—	—	—	—	—	18132	903244	Swingbridge at Bergumerdam.
						9538	733717	Lock at Lemmer.
						3341	232552	Lock at Stavoren.
	—	—	—	—	—	11636	552451	Bolswarderbrug.
						10138	612725	Large lock at Harlingen.
	—	—	—	80	4	8568	390325	Bridge at Diever.
	—	—	—	—	6	18085	1093371	Lock at Zwartsluis.
	—	—	—	—	—	10747	504469	Balkbrug.
	—	—	—	—	—	7835	169094	Between the Regge and Almelo.
						8165	172442	Between Daarle and the Vecht.
	100	100	—	—	4	12766	746337	Lock at Katerveer.
	—	—	—	—	2	1496	66961	Lock near Hezenberg.
	150	150	150	150 (2)	10	94063	—	Lock on the Zuiderzee.
	200 to150	150 to125	125	150 (2)	7, or 10 of 13 M.	8710	461348	Lock at Purmerend.
						27024	1232642	Locks near Amsterdam.
	150	125	—	—	12	17266	1149893	Swingbridge at Maarssen.
						17431	1422147	Locks at Amsterdam.
	130	(3)	—	—	12	16916	709269	Old lock at Vreeswijk.
						25958	1076228	Lock at Utrecht (Vecht).
. . .	. . .	—	—	150 to 80	—	—	—	
. . .	. . .	—	—	100 to120	—	25394	2026377	Lock at Gouda (Mallegatsluis).
. . .	. . .	—	—	—	—	13544 (†)	842866	New lock on the Amstel at Leimuiden. (†) of which 5301 are steamboats.
. . .	. . .	—	—	100	—	39221	—	at Amsterdam.
	—	—	—	—	—	82250	1339617	at Delft.
	—	—	—	—	—	44421	1032841	Lock at Leidschendam.
	—	—	—	—	8	10458	294010	Lock near Gouda.
	150	150	125	—	8	7173	524363	Lock at Nieuwesluis.

NAME OF CANAL.	Minimum dimensions of canal.			Maximum dimensions of boats or steamboats (s).			
	Width at floating line. M.	Width at bottom. M.	Depth. M.	Length. M.	Width. M.	Draft of water. M.	up to 1
Canals in the provinces of North Brabant and Limburg.							
22. Canalised Dieze (from Bois-le-Duc to the Maas)	54.40	40	2.40	56	11.80	1.90	. . . .
23. South Willemsvaart (from Bois-le-Duc to Maestricht)	18.40	10	2.10	50	5 (4)	1.90	. . . .
24. Canal from Maestricht to Liege	—	9 to 11	2.10	50	5 (4)	1.90	120
Canals in the province of Zeeland.							
25. Canal across South-Beveland	40	10	6.50	100	15.75	6.20	250
26. Canal across Walcheren (Flushing—Veere) .	50 to 60	8 to 21	7.45	130	19.75	7.10	250
27. Canal from Terneuzen to Ghent	47.25	17	6.05	90	11.50	5.61	250

(*) The Merwede canal was opened up to Vreeswijk on August the 4th 1892.
(1) at night 133 M.
(2) at night 100 M.
(3) Speed must be reduced to 75 M. in the centre of villages.
(4) With a special permission boats of a width of 6.60 M. may navigate the canal.
(5) With a special permission the speed may be increased up to 180 M.

d in M. per minute elling single.				Maximum speed for tugs in M. per minute.	Maximum number of boats in a tugged train.	Annual movement of inland navigation boats 1892.		
r in M.								
1 0	2.01 to 2.50	2.51 to 3.00	more than 3.00			Number of boats.	Total tonnage in cub. metres.	P L A C E.
. .	—	—	—	120	6	16740	1342417	Lock at Crèvecoeur.
. .	—	—	—	90	4	5497	641551	Lock n° 6 between Veghel and Helmond.
						4032	494518	Lock n° 16 near Weert
100)	—	—	-	-	4	6753	835542	Lock at Maestricht.
)	150	150 to 125	125	—	18	32763	3468697	Locks at Hansweert.
)	150	150 to 125	125		12	7753	755178	Locks at Veere.
						6261	335235	Locks at Flushing.
)	170	170 to 145	145	--	12	6293	581250	Locks at Sas van Gent.

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